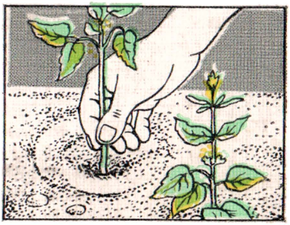
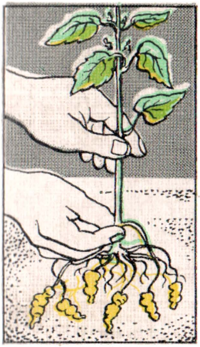
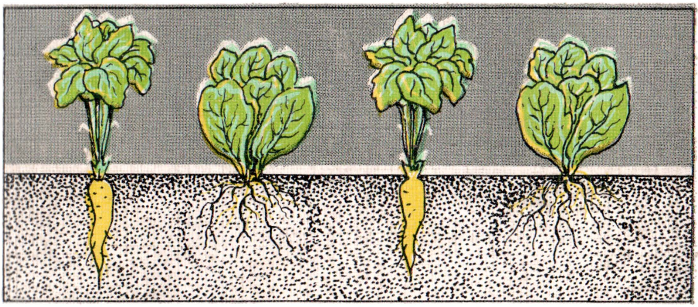
Vegetable Growing in Home Gardens of Tropical and Subtropical Areas

P. F. KONONKOV
and
Vemulapalli KIRAN







Mir Publishers Moscow

Vegetable Growing in Home Gardens of Tropical and Subtropical Areas

П. Ф. КОНОНКОВ,
ВЕМУЛАПАЛЛИ КИРАН

Приусадебное овощеводство в тропиках и субтропиках

Университет дружбы народов
Москва

Vegetable Growing in Home Gardens of Tropical and Subtropical Areas

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MANUAL

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PREFACE
TO THE ENGLISH EDITION

Nearly everyone becomes involved in vegetable gardening at least once in their lifetime. In doing this he or she functions as either the gardener, the visitor, or the vegetable taster.

Home gardens provide a family with vegetables, and in many countries these plots are still the basic source of vegetable products. Even in industrial countries private plots located in rural areas produce abundant vegetable yields, although for their owners they may serve more as a source of recreation than of food products. In times of danger that may face a country, personal plots may acquire a great significance in providing the citizens with horticultural products.

In our technological age, when chemicals have become an indispensable part of the commercial vegetable industry, we strive to cultivate vegetable crops without the application of herbicides and with minimal amounts of mineral fertilizers and pesticides. This, however, is only achievable in home gardens where all the family members can take part in the gardening chores during their leisure time.

To meet all the nutritional requirements, one should cultivate a wide range of greens, most of which have a poor storage ability and do not tolerate transportation. Greens have thus become a number one crop for the amateur vegetable grower.

A home vegetable garden is also a great help to the family budget considering the constantly rising price of food.

In some tropical countries a number of private vegetable growers have organized cooperatives for exporting their vegetable products to countries of cooler climate. Thus, amateur gardening is becoming a highly commercial venture, which can provide a source of hard currency.

Finally, a private vegetable plot is in a way a "testing area" where a professional cultivator or a seed specialist can test new varieties and evaluate recommendations. It is of interest that in his welcoming address to the 20th Congress of the International Seed Testing Association (ISTA), the Minister of Agriculture and Food of Canada noted that farmers and everyone engaged in agriculture rely upon the Ministry's recommendations since they have already been approved by the Ministry staff on their own farms. The best scientific recommendations are then introduced into practice all over the country.

Numerous textbooks, monographs, and special and popular books and booklets on vegetable cultivation and production in the agricultural industry have been published while there are still a limited number of publications available concerning amateur vegetable gardening. The most interesting books in our opinion are "1 × 1 des Bio-Gärtners" by Marie Luise Kreuter published in Munich, Vienna, and Zurich in 1984, and the reference book "Vegetables" by Tony Biggs published in London in 1982. These books, however, are concerned with vegetable gardening in Germany and Britain—a rather narrow climatic region.

At the same time there are wide regions in the tropics where amateur vegetable gardening has its own specific features. To fill this gap we delivered courses of lectures between the years 1967 and 1986 on "Vegetable Cultivation and Production in the Tropics" to the students of the Department of Agriculture at the P. Lumumba Peoples' Friendship University and published a textbook entitled "Vegetable Growing in Home Gardens of Tropical and Subtropical Areas" in 1984, which is now available in English from MIR Publishers.

We would sincerely appreciate receiving critical comments and suggestions from the readers. They will be given serious consideration in our future work.

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D. Sc. (Agr.)

June 26, 1987

CONTENTS

Preface 5

Introduction 9

1. The Nutritional Value of Vegetables 14

2. Classification of Vegetable Plants 30

3. Requirements for Environmental Conditions 35

Soil Requirements for Growing Vegetables 50
Mechanical Composition of Soil 52
Water in the Soil 58
Nutrients and Their Influence on the Growth and Development of Plants 70
The Regulation of Environmental Conditions in Home Garden Vegetable Growing 74
Methods for Increasing Soil Fertility 78

4. The Species Composition of Vegetable Crops Cultivated in Home Gardens of Tropical and Subtropical Areas 83

Selection of Vegetable Crops 101
Length of the Vegetation Period 103

5. The Land Plot; Its Location, Size, and Cultivation 109

Location of Crops 113
Soil Cultivation 114

6. Succession Croppings and Intermediate Sowings 117

Compatibility of Vegetable Crops 125

7. Field Management for Growing Vegetable Plants 130

Fertilizers 130
Sowing and Planting 135
Areas for Plant Nutrition 142
Irrigation 144
Harvesting 146

8. The Cultivation Calendar for Vegetable Crops in Tropical and Subtropical Areas 150

INTRODUCTION

Today, mankind is worried about the possibility of satisfying its future demands for foodstuffs.

The most alarming situation exists in the developing countries. Suffice it to say that every day ten thousand people (P. Sharkhan', 1982) die from hunger and diseases caused by malnutrition, and in the developing countries, according to UN food organizations, about twenty-five million people die from hunger and exhaustion every year. Chronic malnutrition or, in better circumstances, undernourishment happens to be a great hazard for the lives of many people.

It is especially dangerous for children, because nearly half of all pre-school children in developing countries are deprived of normal nourishment, which causes various physiological disorders and leads to mental and physical retardation. Among those sections of the population where the nutrition requirements are more or less met, the problem lies in the monotonous traditional diets, which engender diseases typical of one or another diet. Thus, a balanced diet is the main problem for many developing countries.

The problem is aggravated by the high growth rates of the population of these countries, where the land resources are limited. It is notable that in the countries of Southeast Asia, where 70 per cent of the world population lives, the land area constitutes less than 30 per cent of the earth's total. It is befitting to mention the amount of land per capita in different countries. On the average, per each inhabitant of the earth there is nearly 0.3 ha of arable land, including 470 sq m of irrigated land (see Table 1), available. This index varies greatly by country. In the USA, for instance, there is about 1 ha of arable land per capita, in India there is 0.27 ha and in Indonesia, only 0.1 ha (FAO, 1980).

Table 1

Comparison of Land and Population Characteristics of Developed and Developing Countries

Countries	Land, %		Population, %	Annual population growth, %	Share in world production, %	Average land per person:	
	Arable	Irrigated				Arable land, ha	Irrigated land, sq m
Developed	48	28	26	0.88	60	0.55	502
Developing	52	72	74	2.36	40	0.21	457
The whole world	100	100	100	1.93	—	0.30	469

In the developing countries, where 52 per cent of the arable land and 72 per cent of the irrigated land are concentrated, and 74 per cent of the world population live, only 40 per cent of the world foodstuffs is produced.

At present, the world population increases by 180 000 people per day. It is estimated that at the present growth rates, the population of the developing countries alone will be 4-4.5 billion people by the year 2000. However, if the available lands are properly exploited and the climatic conditions are favourable, these countries can produce food for many more people.

Vegetables will play an important role in solving the problem of increased food production and providing a balanced diet. Besides high productivity, vegetable crops have a high nutritive value. Many vegetable crops, especially tuberous plants, can quite successfully constitute the bulk of foodstuffs, in addition, some vegetables can serve as an indispensable source of certain nutritive substances. That is why, in many developing countries, national agricultural development programmes are focussed on the need to increase the production of vegetables in order to increase their proportion in the daily food ration. Despite all the favourable factors for vegetable growing, their production and consumption in the developing countries of tropical and subtropical zones is at an extremely low level.

According to recent FAO data, the annual consumption of vegetables in the world is approximately 250 mln tons. In different countries, the annual vegetable consumption per capita varies greatly: from 2 kg (in Mauritania) to 195 kg (in Portugal). Most of the developing countries fall under the category of countries with insufficient vegetable consumption (under 25 kg) per capita per annum. Scientists recommend that a person consume approximately 100-120 kg of vegetables per year. To provide the population with the necessary varieties of vegetables, many developing countries need to significantly increase the production of vegetables.

There are two ways to increase the production of vegetables: they can be grown on large areas using industrial technologies, or they can be grown on small peasant farms and in home gardens. At present, the first method is of limited value to developing countries because of the low level of mechanization in agriculture and because vegetable growing on large areas is connected with high labour and material expenditures. Thus, home gardening becomes a decisive factor. In addition, it allows for the inclusion of lean and less fertile lands in production without significant effort. These plots can be very effectively used. On such lands it is possible to simultaneously grow various varieties of vegetable crops and, consequently, obtain a high yield per unit area. But success here depends on the knowledge of the requirements of vegetable crops, on the right selection of crops, keeping in mind the region and season of cultivation, and finally, on the compatibility and advantage of growing different vegetables in mixed plantations.

Besides their high nutritive value, the productivity of vegetables is 5-10 times more than the crop capacity of any cereal crop. As was mentioned, the land resources of many countries are limited and the densities of its populations and their growth rates are the highest. Under such conditions, it is very important to obtain the maximum output of agricultural production per unit area within the shortest period of time. Vegetable crops best satisfy these demands; therefore, they are becoming more and more widespread in large-scale farms, as well as in small-scale home gardens, in rural and urban areas.

Vegetable growing in home gardens in many countries not only meets the home requirements, but in some cases, it is also the main source of vegetables for large populated areas. Trade associations, organized by members of several home gardens, export vegetables to the northern regions, thus becoming an important currency source.

Unfortunately, there are not enough textbooks or manuals that more or less thoroughly describe vegetable growing in tropical and subtropical areas; most books do not contain any information on vegetable growing in home gardens in these regions. The present manual on vegetable growing in home gardens of tropical and subtropical areas is written to fill the gap in this field.

1

The Nutritional Value of Vegetables

The nutritional value of vegetables is great and is determined by their content of carbohydrates, proteins, fats, vitamins, and minerals. Carbohydrates, proteins, and fats are the main source of energy required for the vital activity of the human organism, and the role of vitamins and minerals is confined to the regulation of tissue activity and metabolism (see Fig. 1). Apart from their main rôle, these substances perform specific functions in metabolism. For example, the aminoacids that make up proteins are necessary for the growth, regeneration of tissues, and synthesis of many proteins. Fats are necessary for the heat insulation of the body, and carbohydrates take part in all the processes of energy conversion.

The caloric value of vegetables in comparison to that of products of animal origin and grain is not great because vegetables contain an insignificant amount of such caloric compounds as fat and protein. It is noteworthy that 1 g of fat contains 9.3 cal, and 1 g protein contains 4.1 cal; but 1 g of carbohydrates, which are the main energy source of vegetables, can yield only about 3.75 cal (G. Herklots, 1972). However, vegetables are comparable to cereals in terms of the gross yield of calories per hectare of land. For example, on the average, wheat yields 8 700 000 kcal, tomato

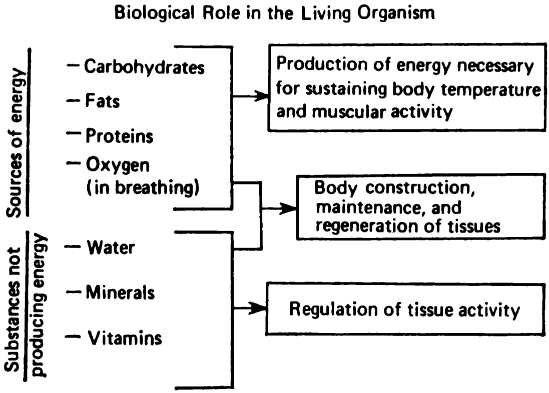
Biological Role in the Living Organism
Sources of energy
— Carbohydrates
— Fats
— Proteins
— Oxygen (in breathing)
Substances not producing energy
— Water
— Minerals
— Vitamins
Production of energy necessary for sustaining body temperature and muscular activity
Body construction, maintenance, and regeneration of tissues
Regulation of tissue activity

Figure 1
Classification of nutrients (acc. to I.S. Dema, 1965)

yields 12 540 000 kcal, and white cabbage 6 000 000 kcal. This yield is connected with the high productivity of vegetable crops.

An adult needs about 3000-4000 kcal daily. However, this index is dependent on the sex and age of the person (Table 2). According to the new standards set forth by the Nutrition Institute of the USSR Academy of Medical Sciences, the average energy requirement is 2 800 kcal per day, and the average protein requirement is about 85 g per day.

It is necessary to state that the caloric and protein content in the diet of the population of many developing countries does not reach the recommended level.

For instance, according to the FAO statistics (1981), in such countries as India and Bangladesh, a person consumes half the amount

Table 2

Energy and Protein Requirements of Human Beings (FAO, 1979 and Harrison, 1979)

Age, sex, and condition of the human organism	Requirement	
	Energy, kcal/kg of weight/day	Protein, g/day
Up to 1 year	112	20-40
1-9 years	90	30-50
10-19 years	55	50-80
Grown-up man	46	50-90
Grown-up woman	40	40-70
Pregnant woman	45	55-90
Nursing woman	55	55-90

of calories and protein as that consumed in developed countries. Although the energy provision of food available in these countries exceeds the critical level, at the same time, it is much lower than the average caloric requirement. The critical level (based on the basal metabolic rate) (1600 cal) is the quantity of energy spent by the organism at rest (Fig. 2).

There are two indices that should be distinguished: one is the average consumption of calories per capita and the other is the number of people whose food supplies less calories than that required by the basal metabolic rate (Table 3).

As is clear from the data in Table 3, nearly 297 million people in the Far East alone are underfed, and this situation is worsening every year.

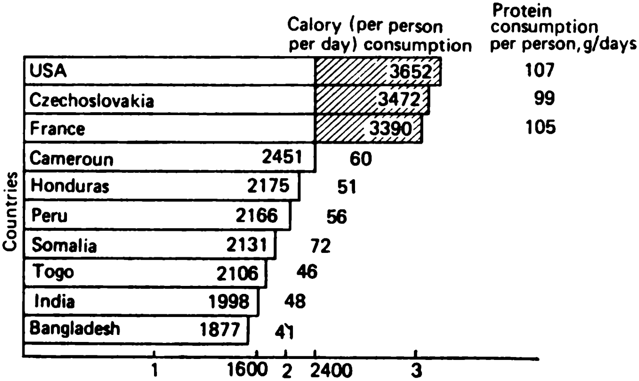

Figure 2
Consumption of calories and protein in various countries of the world (FAO, 1981)
Conventional designations:
1600 cal, basal metabolic rate; 2400 cal, average requirement; 60-80 g, average daily protein consumption requirement per person

In the developed countries, the problem is to increase the proportion of protein and calories of vegetable origin in the total quantity

Table 3

Number of People Consuming Food of Lower Caloric Value than That of the Critical Level (Million People)

Geographical region	Years	
	1969-1971	1972-1974
Near East	31	20
Latin America	44	46
Africa	70	83
Far East	250	297

of consumed energy. A person's daily ration should include vegetables and tubers constituting, on the average, 15-20 per cent of the total caloric value of the ingested food.

Carbohydrates are found in vegetables mainly in the form of starch. In addition to their role as a source of energy for the human organism, they provide for the normal conversion of the main metabolites formed during the process of protein and fat catabolism. Table root crops, corn, and legumes contain the largest amount of carbohydrates. It is notable that these vegetables contain not only carbohydrates but also vitamins and minerals that are lacking in cereals. The daily requirement for carbohydrates is 400-500 g, out of which 50-100 g are monosaccharides and disaccharides and 400-450 g are starch.

Proteins are present in vegetables in small amounts, ranging from 0.5 g (melon and watermelon) to 7.6 g (green peas) per 100 g of the edible part (Table 4). The biological value of food products containing proteins of animal origin is much higher, but it is possible to provide adequate and complete protein intake by using only foodstuffs that contain animal and vegetable proteins in a definite ratio. They have an important biological role in the organism. Proteins serve as both structural material and, at the same time, as a source of energy. Plants that are richest in proteins are the young leaves of manioc (Manichot utilissima), spurge (Euphorbia pulcherrima), Gnetum gnemonoides and Morinda citrofolia.

Table 4

Nutritional Content in Vegetables per 100 g of Edible Part (from K. W. King, 1971)

Crop	Caloric value		Protein, g	Ca, mg	P, mg	Fe, mg	Vitamin content				
	Calories	Joules					A, µg	B_1, mg	PP, mg	C, mg	B_2, mg
Pumpkin	31	130	0.6	19	22	0.5	920	0.04	0.5	15	0.04
Watermelon	23	96	0.5	6	7	0.2	70	0.02	0.2	5	0.03
Melon	25	104	0.5	15	15	1.2	350	0.04	0.6	29	0.03
Chayote	31	130	0.9	12	30	0.6	5	0.01	0.4	20	0.04
Cabbage	28	117	1.7	43	36	0.7	30	0.06	0.3	43	0.04
Tomato	21	88	0.8	7	24	0.6	180	0.06	0.7	23	0.05
Brinjal	27	113	1.0	23	31	0.8	0	0.04	0.8	5	0.04
Bean	36	150	2.0	55	45	1.7	110	0.08	0.6	18	0.11
Okra (gumbo)	42	176	2.2	78	62	1.1	100	0.06	1.1	29	0.12
Shallot	72	301	2.6	37	60	1.3	0	0.06	0.2	1	0.02

Table 4 (*concluded*)

Crop	Caloric value		Protein, g	Ca, mg	P, mg	Fe, mg	Vitamin content				
	Calories	Joules					A, µg	B_1, mg	PP, mg	C, mg	B_2, mg
Green peas	97	405	7.6	24	124	2.0	215	0.38	2.2	26	0.14
Carrot	41	171	0.8	34	26	0.9	3530	0.06	0.6	5	0.04
Beet	44	184	1.7	14	38	0.8	0	0.01	0.2	5	0.04
Cucumber	15	63	0.7	16	24	0.6	5	0.03	0.2	14	0.04
Onion	45	188	1.4	30	40	1.0	5	0.04	0.3	10	0.03
Turnip	27	113	0.8	32	26	0.4	0	0.03	0.5	28	0.03
Pepper	38	159	1.9	20	28	1.7	470	0.09	1.5	91	0.13
Swiss chard	27	113	1.6	110	29	3.6	875	0.03	0.4	34	0.09
Radish	23	96	0.9	26	30	1.2	0	0.03	0.3	28	0.03
Lettuce	13	54	1.0	16	23	0.4	0	0.05	0.3	7	0.03
Sweet potato	116	485	1.3	31	37	1.0	1815	0.11	0.8	31	0.04

From 4 to 10 per cent of their wet weight consists of protein (Terra, 1968).

Black nightshade is particularly rich in protein. Its young leaves and berries can be eaten fresh or slightly cooked. One hundred grams of the fresh leaves of this plant contain about 2-6 g of protein that is rich in methionine (an aminoacid rarely present in other vegetables). Young beans, peas, and also leafy vegetables are none the less rich in protein. The daily requirement for protein is 60-80 g.

Fats are present in vegetables in small amounts. They are necessary not only as a form of energy storage in the organism, but also for the thermal insulation of the body. Vegetable and animal fats and oils are the main sources of fat. Of the vegetables, beans and peas are richest in fats (averaging up to 3 per cent of the raw weight). If a food is rich in carbohydrates and low in fats, the organism may replenish fat stores at the expense of carbohydrates and thus compensate for the lack of fats in the food. A certain minimum quantity of fats, particularly unsaturated fats, which are abundant in vegetable fats and oils, is required irregardless of climatic conditions (Harrison et al., 1979).

Vitamins, when compared with the basic nutrients (proteins, fats, and carbohydrates), are required in the smallest quantities. They function as catalysts in a living organism. Vitamins cannot be produced by an organism, thus, they are available only through foodstuffs of vegetable and animal origin in which the vitamins have been priorly accumulated from vegetable sources. Vitamins are not a source of energy. An absence or deficiency of vitamins causes avitaminoses and hypovitaminoses, including scurvy, rickets, pellagra, night blindness and beriberi, a widespread disease in the countries of Southeast and Central Asia. Vegetables contain some of these vitamins, in appropriate proportions, which is very important in a vitamin-balanced diet (Table 5). Raw vegetables are most valuable in this respect, because many vitamins, for example, vitamin C and vitamins of the B-complex, are not stable at high temperatures. In addition, a vegetable such as cabbage contains the vitamin "U".

Minerals. Among the minerals, iron, sodium chloride, iodine, and calcium are most important for the vital activity of a human organism.

The human organism maintains an equilibrium between the entry of each of these elements and their excretion. They play a major role in the functioning of the organism. First, they compose the skeleton and make it strong. Second, mineral salts, maintaining the acid-alkaline balance in the organism, provide for the normal metabolism and regular functioning of all systems of vital activity in the organism. Third, minerals are components of such compounds as haemoglobin, enzymes, vitamins, hormones, etc. Table 6 presents the main minerals, their function in the organism, and the vegetables that are rich in them. Most of the ash elements are contained in spinach, horseradish, dill, leaf cabbage, and sorrel.

Table 5

The Major Vitamins, Their Functions, Requirement and Sources*

Vitamin	Biological function	Daily requirement, mg	Main sources	Vitamin content in vegetable crops, mg %
A	Promotes normal metabolism, the growth and development of the organism; provides for the normal function of epithelium, skin integuments and mucous membranes, sweat, sebaceous and tear glands, organ of vision	2.5	Butter, egg yolk, liver, fish, fresh vegetables	Spinach, Swiss chard—5.0, carrot—1.5
B_1 (thiamine)	Antineuritic, turns into cocarboxylase in the organism, component of a number of enzymes, participates in carbohydrate metabolism	2.0	Vegetables, meat and non-threshed grain	Lettuce—0.90, Swiss chard—0.26, pea—0.25
B_2 (riboflavin)	Regulation of nervous system, redox processes; participates in the optic function of the eye and the synthesis of haemoglobin	2.0-3.0	Grain, leafy vegetables, meat, milk, liver	Swiss chard—0.56, bean—0.23, kohlrabi—0.19

Table 5 (*continued*)

Vitamin	Bioiogical function	Daily requirement, mg	Main sources	Vitamin content in vegetable crops, mg %
B_6 (pyridoxine)	Antidermatitic component of enzymes, plays an important role in fat metabolism	2.0-2.5	Rice bran, wheat germs, yeast	Horseradish, garlic, rooted parsley, sweet pepper
B_{12} (cobalamin)	Antianemic	0.001	Liver, kidneys	Lettuce
PP (nicotinic acid)	Antidermatitic, participates in cellular respiration; a shortage in the organism results in significant derangement of metabolism, dystrophic and degenerative alterations in all organs and tissues, more pronounced in the skin, nervous and digestive systems	20-25	Meat, fish, nuts, milk	Swiss chard — 3.30, potato — 1.20, cauliflower — 2.0
B_c (folic acid)	Antianemic	2.0	Leafy vegetables, liver	Leafy parsley, spinach, lettuce, bean, horseradish
Pantothenic acid	Hair and skin pigmentation	12	Yeast	Leafy vegetables

Table 5 (*concluded*)

Vitamin	Biological function	Daily requirement, mg	Main sources	Vitamin content in vegetable crops, mg %
C (ascorbic acid)	Antiscorbutic, plays an important role in redox processes, carbohydrates metabolism, normalization of blood vessel permeability	100	Vegetables and fruits	Pepper — 111, pumpkin — 96, beet — 88, kohlrabi — 85
D	Antirachitic, takes part in the regulation of calcium and phosphorus metabolism	0.025	Liver, butter, milk, fish	
E	Promotes normal functioning of the reproductive organs	5.0	Grain, butter, meat, green leaves, eggs	Leafy vegetables
K	Antihaemorrhagic	0.015	Spinach, cabbage	Leafy vegetables
P (rutin and other flabonoids)	Regulation of blood vessel permeability	50	Black currant	Pepper and leafy vegetables

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* The table is derived from the data published in the following books: Grebinsky S.O., *Biochemistry of Plants* (Moscow, 1975); Kretovich V.L., *Biochemistry of Plants* (Moscow, 1980); Dema I.S., *Nutrition in Relation to Agricultural Production* (Rome, FAO, 1965); Choudhury B., *Vegetables* (New Delhi, 1979); *Guidebook of a Practitioner* (Moscow, 1981).

Table 6

Major Minerals, Their Functions in the Organism, and the Vegetables Most Rich in Them (from I.S. Dema, 1965)

Element or salt	Functions	Vegetables with highest content
Calcium	Formation of bones, prevention of rickets and tooth rot	Eggplant, chiver, Swiss chard, cabbage, bean
Phosphorus	Formation of bones, nervous tissues and muscle contraction	Green peas, eggplant, shallot, bean, bulb onion
Iron	Formation of red blood cells	Swiss chard, green peas, bean, pepper, shallot
Iodine	Prevents swelling of the thyroid gland. Provides for its normal functioning	Carrot*, watercress**
Sodium chloride and potassium chloride	Improve the appetite, maintain the liquid balance in the organism, prevent exhaustion of the muscular and nervous systems	Horseradish, celery, leafy parsley, green onion, spinach, chinese cabbage, small radish
Cobalt	Component of vitamin B_{12}, which promotes the growth and formation of blood	Lettuce, bean
Zinc	Necessary for the normal functioning of glycolysis in the organism; required for growth and maturation	Cabbage*

Table 6 (*concluded*)

Element or salt	Functions	Vegetables with highest content
Nitrogen	Component of proteins	Legumes
Copper	Necessary for blood formation and hair pigmentation	Cabbage, leafy vegetables
Sulphur	Component of specific proteins	Onion, cabbage
Fluorine	Concentration in drinking water satisfies the needs of the organism and prevents tooth rot	

---

* It also contains the largest quantity of boron.

** According to the data of the authors of the book, watercress contains 0.5 mg per kg of dry matter; when cultivated by the method developed at the All-Union Research Institute of Selection and Seed Growing of Vegetable Crops, the iodine content may be increased to 1.1 mg per kg of dry matter.

Table 7

The Role of Vegetables in Meeting the Daily Requirements of Macro- and Trace Elements (from Andryushchenko et al., 1981)

Element	Daily requirement, mg	Amount supplied by vegetables, mg	Extent of satisfaction, %	Vegetables richest in macro- and trace elements
		Macroelements		
Sodium	4000-6000	112.8	2.8-1.9	Tomato, onion, garlic, beet, cabbage
Potassium	2500-5000	189.6	7.6-3.8	Tomato, cabbage, carrot
Calcium	800-1000	144.1	18-14	Cabbage, carrot, onion, garlic, tomato
Magnesium	300-500	97.3	32-19	Tomato, carrot, cabbage, beet
Phosphorus	1000-1500	194.7	19-13	Garlic, cabbage, carrot, cucumber, green peas
		Trace elements		
Iron	15.0	2.7	18	Cabbage
Zinc	15.0	1.6	11	Carrot, beet
Manganese	10.0	1.3	13	Cabbage, beet
Copper	2.0	0.4	20	Cabbage, carrot, tomato
Fluorine	1.0	0.1	10	Tomato
Molybdenum	0.5	0.05	10	Cabbage, carrot
Selenium	0.5	0.01	2	Beet, cabbage
Chromium	0.3	0.06	20	Tomato, beet
Cobalt	0.2	0.01	5	Cabbage, carrot, sweet pepper

Vegetables are rich in minerals: they contain over 50 elements. The mineral requirement for a human organism is only to a small extent met by the consumption of vegetables (Table 7) because of the limited consumption of crops. A wider variety of crops will help to meet these requirements more fully.

It should be noted that the mineral complexes of meat, fish, and bread products create an excess of acid in the organism which disrupts the protective mechanisms and metabolic processes. Vegetables neutralize these substances, thus providing for normal metabolism and an alkaline blood reaction. The daily human requirement for iodine is between 100 and 200 millionth of a gram. Watercress (0.448 mg per 1 kg of dry matter), tomato, and sweet pepper contain the largest amount of iodine.

2

Classification of Vegetable Plants

There are many classification systems for vegetable crops, but the most common are the following:

Botanical classification. Vegetable plants belong to the Angiospermae, which is subdivided into two classes: monocotyledonous and dicotyledonous. These classes are further divided into families, genera, species, subspecies, and botanical varieties. All basic vegetable plants belong to mainly 18 families (Table 8).

Classification of vegetables based on the part of a plant used as food. This classification is widely accepted in commercial vegetable growing. Vegetables are divided into groups depending on the part of the plant used as foodstuffs (Fig. 3).

According to this classification, vegetables are divided into: leafstem, fruit-bearing, flowering (broccoli, cauliflower), root and tuber plants.

E. Mortenson and E.T. Bullard (1968) suggest one more classification system for tropical vegetable crops based on their importance and marketability. The authors think that tropical vegetables can be divided into four groups:

1. Crops of high commercial value: onion, peanut, cabbage, sweet pepper, hot pepper,

Table 8

Botanical Classification of Vegetable Crops

No.	Name of the family (Latin)	Main vegetables in the given family
	Monocotyledonous	
1	Alliaceae	Various species of onion
2	Asparagaceae	Asparagus
3	Araceae	Taro (colocasia esculenta)
4	Dioscoreaceae	Yam
	Dicotyledonous	
5	Aizoaceae	New Zealand spinach
6	Chenopodiaceae	Beet, Swiss chard, spinach, goosefoot
7	Asteraceae	Topinambour, chicory, endive, lettuce, artichoke, Scorzonera
8	Brassicaceae	Various species of cabbage, broccoli, kohlrabi, rutabaga, turnip, mustard, horseradish, radish, crambe, cress
9	Convolvulaceae	Sweet potato
10	Cucurbitaceae	Various species of pumpkins, watermelon, melon, chayote, marrow, scallop squash, cucumber, sponge gourd, bittergourd, pointed gourd
11	Euphorbiaceae	Manioc
12	Fabaceae	Peas, beans, China bean, cow peas, soya bean
13	Malvaceae	Okra
14	Polygonaceae	Rhubarb, sorrel
15	Solanaceae	Early potato, brinjal, tomato, pepper, ground cherry, pepino

Table 8 (*concluded*)

No.	Name of the family (Latin)	Main vegetables in the given family
16	Apiaceae	Carrot, parsley, celery, parsnip, dill, anise, chervel, coriander, fennel, caraway
17	Lamiaceae	Basil, hyssopus, marjoram, balm, mint, rosemary, savory, thyme, stachys
18	Poaceae	Maize or corn sugar

watermelon, melon, cucumber, yam, sweet potato, tomato, manioc, beans, and brinjal.

2. Crops of limited commercial value: garlic, celery, cauliflower, broccoli, taro, lettuce, luffa, potatoes, and certain species of beans.

3. Crops grown for a local market: shallot, beet, turnip, Chinese cabbage, green mustard, cabbage, Brussels sprouts, kohlrabi, endive, chicory, jute, pumpkin, artichoke, carrot, fennel, okra, gumbo, parsley, radish, watercress, chayote, spinach, corn, etc.

4. Crops grown mainly for home consumption: chives, dill, chervel, horseradish, asparagus, parsnip, portulaca, rhubarb, and many spices and aromatic herbs.

A classification system for vegetables based on the season of their preferable cultivation is also used.

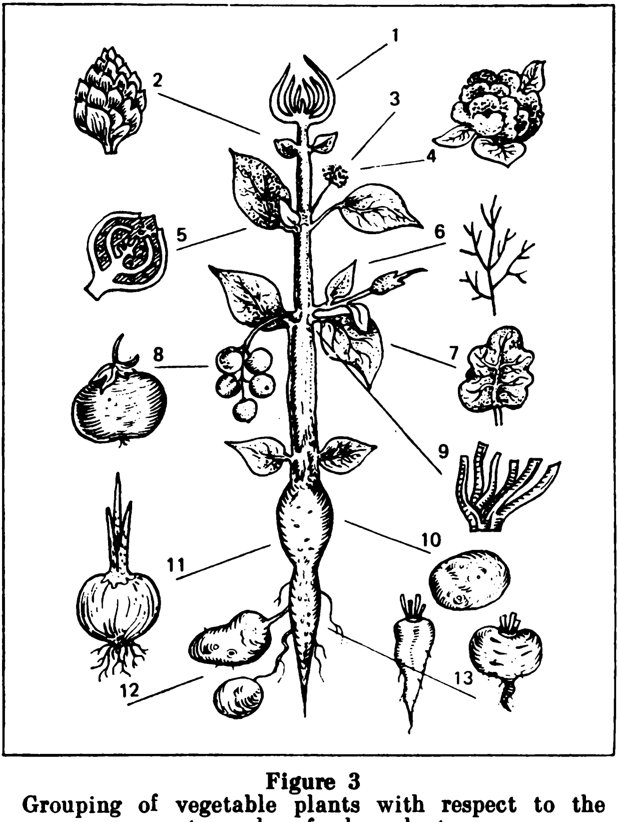

Figure 3
Grouping of vegetable plants with respect to the parts used as food products:

1—large terminal bud (cabbage); *2*—flower bud (artichoke); *3*—floscule (hyssopus); *4*—shortened flower stem (cauliflower); *5*—axillary bud (Brussels sprouts); *6*—young sprouts (cress, mustard, purslane, etc.); *7*—leaves (dill, spinach, lettuce, etc.); *8*—fruits (most of the vegetables: tomato, watermelon, cucumber, brinjal, pumpkin, melon, peas, beans, etc.); *9*—cuttings (rhubarb, celery, leaf beet, leek); *10*—tuber-bearing plants (potato, taro); *11*—bulbs (bulb onion); *12*—root crops tuber-bearing plants (manioc, sweet potato); *13*—root-bearing plants (small radish, carrot, beet, turnip, chayote)

Classification of Vegetables by the Growing Season in the Tropics (Based on the Example of India) (from G. Blumenfeld, 1968)

I. Rainy-season vegetables: okra, tomato, cucurbits, radish, beans, hot pepper, brinjal, sweet potato.

II. Winter vegetables (cold-season vegetables): cabbage, cauliflower, carrot, tomato, beans, peas, onion, hot pepper, radish, turnip, spinach, beet, lettuce and kohlrabi.

III. Summer vegetables (warm-season vegetables): cucurbits, brinjal, okra, gumbo, and many others under irrigation.

Cold-season vegetables include those whose plant parts, i.e. roots, stems, leaves, and buds or unripe flowers (except beans, peas, and hot pepper) are used as food products. Warm-season vegetables are used in their ripe and unripe forms.

The last two classifications are conditional because a vegetable may belong to one or another group, depending on the geographical region it is grown in. Many more classification systems are known, based on the environmental requirements of plants and the methods of field management. They will be dealt with in the appropriate chapters.

3

Requirements for Environmental Conditions

Vegetable crops require different environmental conditions. Considering the fact that the regulation of environmental conditions and the selection of crops in the vegetable garden can be controlled, one must try to satisfy the crop requirements in the best possible way. Vegetable plants, as typical anthropochores (i.e. plants cultivated and distributed by human beings), are more particular about the conditions of growth.

Temperature. Of all the necessary factors for growth, the most important is the temperature of the air. Each type of vegetable vigorously grows and develops only at a specific temperature. If some plants can grow only at temperatures above 10-15°C (tomato and cucumber), others (asparagus, various types of cabbage and greens) can withstand not only long-term cold spells, but also frosts. The minimum and maximum temperatures for the growth and development of the majority of vegetables lie within the range of 4 to 35°C. The optimum temperature, however, depends on the species of the plant and on the phase of its development. The temperature requirements and frost hardiness of various vegetable crops are given in Table 9.

On the basis of temperature requirements, V.I. Edelshtein classifies vegetable plants in-

Table 9

Temperature Requirements and Sensitivity to Frost of Various Vegetable Crops*

Crop	Temperature of growth, °C		Stability to frost	Temperature range for normal growth and development, °C
	Minimal	Optimal		
Artichoke	—	—	Stable (perennial)	15.6-18.3
Asparagus	10	24	Ditto	15.6-18.3
Bean	16	24	Sensitive	15.6-21.1
Beet	4	29	Partially stable	15.6-18.3
Broccoli	4	29	Stable	15.6-18.3
Brussels sprouts	4	29	Ditto	15.6-18.3
Cabbage	4	29	Ditto	15.6-18.3
Carrot	4	29	Ditto	15.6-18.3
Cauliflower	4	27	Partially stable	15.6-21.1
Celery	4	21	Ditto	15.6-21.1
Chinese cabbage	4	29	Ditto	15.6-21.1
Cucumber	16	24	Sensitive	18.3-23.8
Brinjal	16	29	Very sensitive	21.1-29.4
Endive	—	—	Partially stable	15.6-21.1
Garlic	2	27	Ditto	12.8-23.8
Leek	2	27	Ditto	12.8-23.9
Lettuce	2	24	Stable	15.6-18.3
Mustard	4	27	Stable	15.6-18.3
Onion	2	27	Partially stable	12.8-23.8
Parsley	4	27	Stable	15.6-18.3
Green peas	4	24	Stable	15.6-18.3
Pepper	16	29	Very sensitive	21.1-29.4
Sweet pepper	16	29	Sensitive	21.1-23.9
Potato	—	—	Partially stable	15.6-18.3
Sweet potato	—	—	Very sensitive	21.1-29.4
Pumpkin	16	35	Very sensitive	18.3-23.9
Radish	4	29	Stable	15.6-18.3
Spinach	1	21	Stable	15.6-18.3

Table 9 (*concluded*)

Crop	Temperature of growth, °C		Stability to frost	Temperature range for normal growth and development, °C
	Minimal	Optimal		
Squash (summer)	16	35	Very sensitive	18.3-23.9
Squash (winter)	16	35	Ditto	18.3-23.9
Sweet corn	10	29	Partially stable	15.6-23.9
Swiss chard	4	29	Partially stable	15.6-21.1
Tomato	10	24	Sensitive	21.1-23.9
Turnip	—	—	Stable	15.6-18.3
Watermelon	16	35	Sensitive	21.1-29.4

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* From *Vegetable Production Guide for Eastern Ethiopia* (1969) by Haile Michael Kidane Mariam.

to the following five groups:

1. Frost- and winter-resistant: perennial vegetable plants (perennial species of onion, garlic, asparagus, rhubarb, horseradish, and sorrel) which in winter and autumn can withstand frosts up to —10°C.
2. Cold-resistant: biennial cabbage plants, root crops (carrot, beet, root parsley, celery, etc.), onion and greens (lettuce, spinach, and watercress). These plants can withstand temperatures 1-2°C for a long time and frosts of —5°C and lower, for several days.
3. Intermediate between cold-resistant and heat-loving plants: potato and dill.
4. Heat-loving: tomato, pepper, brinjal, pepino, cucumber.

5. Heat-resistant: melon, watermelon, pumpkin, beans and corn.

It should be noted that in the temperate zone plants grow worse and produce fruits later when the day and night temperatures do not fluctuate. This is due to the fact that many vegetable plants under conditions of insufficient illumination need high daytime temperatures to be followed by the lower night temperatures. This reaction to daily temperature fluctuations developed in the course of evolution and is called thermoperiodism. Relatively low night temperatures increase the yield of many vegetable crops in more northern latitudes. It is noteworthy that tropical plants under local conditions either do not react to the fluctuations of daytime and night temperatures, or their reaction is negative, because the fluctuations are minimal in the tropics. As one moves farther north, the fitness of plants to significant fluctuations in temperature and irradiation intensity is more vividly expressed.

In the tropics subzero temperatures are rare and the annual temperature does not fluctuate by more than between 1 and 1.5°C near the equator. Therefore, tropical plants cannot withstand a prolonged cold weather and crops grown in the tropics but originating from areas closer to the north may be damaged by the high temperatures. For this reason the choice of the growing season and of the optimal seeding time is of great importance for growing a specific crop.

The length of the vegetation period, i.e. the period with temperatures at which a complete cycle of the development of plants is possible, has considerable significance for the growth and development of plants. This requirement of crops for warm temperatures during the period of vegetation is expressed by the biological sum of temperatures above 10°C. For example, the biological temperature requirements of the most widespread vegetables at the latitude of 60 degrees are the following: early cabbage, 900°C (start of ripening) and 1400°C (complete harvest); medium cabbage, 1000°C and 1500°C, respectively; late cabbage, 1100°C and 1600°C; carrot, 1550°C and 1900°C; beet, 1450°C and 1850°C. For leafy vegetables the biological sum of temperatures is about 400°C. The sum of active temperatures in the tropics fluctuates from 4000°C to 10 000°C. In the tropics it is possible to grow two, three, and even more harvests a year with artificial irrigation.

Light is the most important ecological factor for nature, because it serves as the only source of energy for the majority of species. The visible range of solar radiation, which we perceive as light, is of primary importance to the life of plants: orange-red and ultraviolet rays have the greatest effect, and yellow-green rays, the least. It should be noted that approximately 1 per cent of the light received by green leaves is used for the synthesis of organic substances, i.e. photosynthesis, and the remaining part is converted into heat, which is used for transpiration or reflected into the atmosphere.

Physiologically active radiation is included in direct and scattered solar radiation. Direct radiation comes to the earth directly from the sun in the form of parallel rays. Scattered or diffuse radiation is the part of the total radiation that reaches the earth after it is reflected and scattered by atmospheric components. During morning hours, more scattered radiation falls on plants, and before sunrise, scattered radiation is the only radiation. The higher the location of the sun above the horizon, the more the amount of direct radiation and the less the amount of scattered radiation that reaches the earth. Scattered radiation prevails during the period of daylight and its spectral composition has more physiologically active emission than that of direct radiation. On clear days scattered radiation makes up from 10 to 15 per cent of the total radiation and on overcast days it is 100 per cent of the radiation.

Scattered light is almost completely absorbed by plants and its utilization ratio is much larger. In northern latitudes the prevailing scattered light is quite enough for photosynthesis, but here temperature remains the limiting factor of productivity.

Solar intensity depends on the geographical latitude of a locality and the time of year. This must be taken into account when selecting crops and also when determining the cultivation season, time of sowing and agricultural methods to be applied. For this the requirements of different vegetable plants for light must be known. Vegetable crops are, therefore, divided into the following groups;

1. Maximum requirement: melon, watermelon, pepper, tomato, cauliflower, marrows, brinjal, corn, bean, peas, and cucumber.
2. Moderate requirement: garlic, radish, dill, onion, beet, carrot, various species of cabbage, and leaf lettuce.
3. Minimum requirement: spinach, head lettuce, rhubarb, green onion, Swiss chard, and parsley.

Meanwhile, the productivity of all of the above-mentioned crops depends to a great extent on the light intensity. Some plants require a low intensity of light only to form more tender and juicy organs that are used as food.

The length of the light period of the day is very important for plant life. The reaction of various plants to the daily fluctuations in radiant energy is called photoperiodism or actinorytism. The length of the day, i.e. of the light period of the day, in the tropics (on the equator) all the year round is about 12 hours. In polar regions the length of the day in summer reaches 24 hours. This fact has a great influence on the distribution of plant species on the earth and on their evolution. The vegetation period of northern plants is adapted to the conditions of a long day, and in the south plants grow and develop in a short day. Owing to this, plants that cannot grow and develop normally without definite and specifically long periods of darkness are called short-day plants or nyctophilic (night-loving) plants. Plants of the high latitudes whose flowering is delayed or does not occur at all in short day conditions (less than 12 hours) are called long-day plants or nyctophobic (non-night-loving) plants. There also exists a group of plants sometimes called intermediate or neutral. Some of them need a long day first and then a short day for their normal development (they are called long-short-day plants). Others need first a short, and then a long, day (short-long-day plants).

Short-day plants, when moved to more northern regions, i.e. to long-day conditions, slow down their development. The growth of the vegetative part and the suppression of flowering are observed. Long-day plants that are grown in the tropics form very little vegetative mass, flowering and fruit formation are suppressed. In the equatorial zone the seasonal changes of the day length are insignificant, therefore, here, under favourable temperature and humidity conditions, plants are hardly influenced by the change of the day length and may be grown throughout the whole year.

According to the photoperiodic reaction vegetable plants can be short-day plants (cucumber, soya, bean, brinjal, pepper, and some varieties of onion and tomato) and long-day plants (lettuce, small radish, spinach, and all the biennial vegetables). There are varieties of tomatoes that grow and develop normally and produce fruit when the day is 15 or 16 hours long. That is why many researchers classify the tomato as an intermediate crop according to the photoperiodic reaction.

The day length has a different influence on the vegetative growth and on the generative development. For example, long-day plants (onion, beet) form storage organs in long-day conditions. However, potato forms tubers better when the day length (for example, in autumn) is less than the optimal day length for the growth and development of the aboveground part (I.M. Kul'tiasov, 1982). In the tropics, under ordinary conditions long-day plants neither blossom nor produce seeds or fruits. The biennial long-day vegetable crops (beet, cabbage) in the tropics yield a commercial harvest during the first year much faster than in Central Europe.

It is worth noting that differences in varieties owing to the photoperiodic reaction are enormous. Varieties bred as a result of long selective processes under local conditions by involving other local varieties are, as a rule, adapted to the local day length. Today, there are many varieties of tomato, onion, garlic, and other crops which, due to the photoperiodic reaction, greatly differ from each other.

All the above-mentioned circumstances must be considered when selecting crops and the season of cultivation, and when solving the problems of international exchanges of plant varieties and seed growing.

Water is the basis of plant feeding. It is a component part of the living cell and it participates, directly or indirectly, in all the processes of cellular vital activity, forming at the same time their medium. Water maintains the turgor in plant tissues, which is necessary for transpiration and plant growth. The edible part of vegetable plants contains a large amount of water. Many vegetables (especially root crops) grown in conditions of insufficient humidity acquire a bitter taste. Furthermore, the lack of water decreases the intensity of photosynthesis and increases respiration which leads to a decrease in productivity and rapid ageing of plants.

The water requirement for vegetable crops is much greater than for other plants. This requirement is expressed as the units of absorbed water required for the formation of one unit of dry matter, and it ranges from 50 (conifers) to 2500 (leafy vegetables). Under the arid conditions of the south of the USSR, the water consumption ratio, which indicates the quantity of water used by the plant and the soil to form one ton of raw plant material, is the following (in tons): cabbage, 250-300; sweet pepper, 200-250; onion, cucumber, and brinjal, 150-200; tomato, 90-150; carrot, 80-120; and beet, 60-90.

It is necessary to note that this ratio depends on the yield: the higher the yield, the less water the plant uses per every ton of output. According to the water requirements, V.M. Markov (1974) classifies vegetable plants into the following groups:

1. High requirement: leafy vegetables (lettuce, spinach, dill, green onions), celery, cole crops (cabbage, small radish, radish, turnip, and rutabaga).
2. Moderate requirement: cucumber, onion, pepper, brinjal, and tomato.

3. Low requirement: root crops, legumes, cereals, and perennial vegetables (asparagus, rhubarb , horseradish).

4. Drought-resistant: watermelon, melon, pumpkin.

It must be stated that the different water requirements are conditioned by two factors: the depth of the location of the root system and its ability to absorb water from the soil, and the intensity of its expenditure to produce a harvest and for transpiration.

The usual rooting depth (m) of different vegetable crops in deep, permeable, well-drained soils (acc. to J. Jenik, 1975) is shown in the following data:

Asparagus	1.8-3.0
Tomato	1.8-3.0
Watermelon	1.8
Pumpkin	1.8
Sweet potato	1.2-1.8
Melon	1.2-1.8
Sugar beet	1.2-1.8
Artichoke	1.2
Legumes, peas, potato, strawberry	0.9-1.2
Parsnip, winter squash, turnip, sweet corn	0.9
Beet, carrot	0.6-0.9
Broccoli, cabbage, cauliflower, spinach	0.6
Onion and small radish	0.3
Lettuce	0.15

The correlation between the water requirement and the rooting depth is not direct, because deep-rooting plants extract water mostly from the upper layers of the soil. Also during different growth periods the water requirement is different. When the plants are young, although they require and use less water, they need highly humid soil and air. This is due to the fact that the root system of young plants is weak and is located in the upper 20-cm layer of the soil that quickly becomes dry.

Of the total absorbed water, plants utilize only from 0.15 to 0.20 per cent. The remaining part evaporates from the surface of the leaves and other aerial parts. This process of evaporation is called transpiration. Transpiration is a physiologically necessary process for plants. Because of transpiration plants obtain water from the soil along with nutrients. At the same time, the leaves are cooled, which prevents overheating and which is especially important for plants grown in the tropics. The intensity of transpiration depends on the biological features of the crop and sometimes on the crop variety and environmental conditions. The intensity or rate of transpiration is the quantity of the water vapour per unit of leaf surface per unit time. Another important index of water exchange by plants is the transpiration ratio, i.e. the quantity of water used by the plant to accumulate 1 g of dry matter. For example, for the major plant crops the transpiration ratio ranges from 100 to 1000 g of H_2O per one gram of dry matter. For such plants as cabbage, cucumber, and lettuce, the transpiration ratio ranges from 450 to 700. It is worth noting that the transpiration ratio depends to a great extent on the weather. It is observed that when the temperature is high and the air is dry, the relative value of transpiration rises. On overcast windy days the transpiration ratio increases.

The productivity, which is the inverse of the transpiration ratio and is characterized by the number of grams of dry matter accumulated in a plant when it discharges 1000 g of water, is an important index. The productivity of transpiration varies from 1 to 8 g of dry matter per 100 g of water.

On the basis of these two factors (the level of development of the root system and the intensity of water expenditure), E.G. Petrov (1955) divides vegetable plants into four groups:

1. Plants that extract water well and intensively use it (beet, rutabaga, etc.).
2. Plants that extract water well, but expend it economically (watermelon, melon, pumpkin, sweet corn, carrot, parsley, tomato, pepper, and bean).
3. Plants that poorly extract water, but expend most of it (cabbage, brinjal, cucumber, cole crops, lettuce and spinach).
4. Plants that extract little water and use it economically (onion and garlic).

The humidity of the air is a significant factor for the growth, development, and productivity of vegetable crops. It affects the water exchange process which is very important for plants. It has an important effect on the process of blossoming and fertilization. It is well known that the viability and fertility of pollen grains greatly depends on the humidity of the air. Different vegetables require different relative air humidity for their growth and development. Cucumber, lettuce, spinach, dill, and celery have high relative humidity requirements (80-90 per cent); tomato, pepper, brinjal, and bean require from 60 to 65 per cent; watermelon, melon, and pumpkin grow and develop well in conditions of low relative air humidity from 45 to 55 per cent (P.I. Patron, 1981).

Air. Atmospheric and soil air are necessary for the development of vegetable crops. Oxygen is used by plants for respiration, and carbon dioxide is used for assimilation. Oxygen makes up 21 per cent of the surface air layer and thus, the above-ground parts of plants contain a sufficient amount of oxygen. There is quite a bit of oxygen in soil air and it enters the soil from the atmosphere mainly by passive diffusion. However, this oxygen is actively used by soil microorganisms for respiration. That is why, for its regular replenishment the soil must be systematically cultivated to keep it loose. When the soil is compacted the gas exchange between soil and atmosphere is hindered.

Atmospheric air contains nearly 0.03 per cent of carbon hydroxide. It is formed in the soil and on its surface as a result of the decay of organic matter by microorganisms and also by the respiration of the root system. Carbon dioxide is, however, used by plants so intensively that the surface air layer is frequently deficient in it, leading to a decrease in photosynthesis. The use of fertilizers along with carbon dioxide improves the growth and development of vegetable crops, it increases the number of leaves, making them larger, and it accelerates and increases the fruit yield. In addition, plants become highly resistant to diseases and pests (Ya.Kh. Pantileev, 1981). It should be noted that in tropical soils, because of the daily and year-round mineralization of organic matters, although delayed, a great amount of hydrogen dioxide is accumulated, which exceeds 4-5 times its quantity in the soils of the temperate belt.

Because of their high productivity vegetable crops are fastidious about carbonaceous feeding. According to V.M. Markov (1974) the optimum concentration of carbon dioxide in the air for the photosynthesis of tomato and radish is between 0.1 and 0.2 per cent; for carrot, cabbage, and potato, it is between 0.2 and 0.3 per cent; and for cucumber, it is between 0.3 and 0.6 per cent.

Wind. Wind has great ecological significance. Its direct influence on vegetable plants leads to increased transpiration and mechanical damage. In addition, wind plays an important role in the displacement of cold and warm air masses, clouds, and fog, which in turn changes the water, heat, and light regime of the given geographical area.

Wind speed increases with an increase in the altitude of the locality above sea level. Wind is important because it helps to pollinate anemophylous plants (sweet corn, beet seed-bearing plants, etc.).

When the wind speed is above 4-6 km/h, it has a negative effect on vegetable plants: the carbon dioxide that is produced by plant respiration at night is carried away, transpiration increases, and the stomata close. Along with this, evaporation from the soil surface increases, the soil dries out and, as a consequence, photosynthesis slows down and the productivity decreases. Wind also causes water and wind erosion of the soil.

Wind has a particularly harmful effect on young plants and on seedlings. According to their wind stability, R. Biyelka (1969) conditionally divides vegetable plants into 3 groups:

1. Sensitive to wind: bean, cucumber, pumpkin, asparagus.
2. Less sensitive to wind: rutabaga, cabbage, Swiss chard, carrot, leek, beans, turnip, beet, and onion.
3. Plants between groups 1 and 2: cauliflower, peas, lettuce, leafy cabbage, small radish, spinach, and tomato.

Wind appears as a result of the difference in temperature and pressure between neighbouring air masses.

Soil Requirements for Growing Vegetables

Soil is a source of nutrients and water for plants. The productivity of plants depends to a great extent on the soil fertility. Fertility is the ability of soil to satisfy the requirements of plants for nutrients and water. Soil fertility depends on physicomechanical and chemical properties and also on the degree of biological fertility. Vegetable crops along with their harvest remove a large number of nutrients from the soil and this is why the soil requirements for growing vegetables increase.

Organic matter (humus) of soil. The humus content of ordinary cultivated soils varies from 0.1 to 4-5 per cent. The humus content of peat soils that are rich in organic substances approaches 50 per cent. However, the proportion of these soils in the total land area of the tropics is insignificant. They are more widely spread along the coasts of the Caribbean Sea (Cuba), in Guyana, Venezuela and other countries. The humus in a 1-m layer consists of the following components (ton/ha):

Peats	750	Dark sierozems	130
Deep chernozems	700	Light chestnut	110
Enleached chernozems	500	Podzols	100
Ordinary and acid chernozems	400	Typical sierozems	80
Red earths of humid subtropics	300	Light sierozems and tundra sierozems	70
Dark chestnut and podzolized wooded steppe	200		

Humus and humic substances are not directly consumed by plants. By accumulating and preserving nutrients humus does not allow them to leach into deeper soil horizons inaccessible to plants. During the gradual mineralization of humus a large number of ash nutrients that are used by plants and microorganisms enter the soil.

Humus and humic substances improve the hydrophysical, chemical, and biological properties of the soil, thus increasing its fertility. Humus plays a significant role in the formation of soil structure. One of the main components of humus is humic acid, which helps plants to grow and develop. Along with it, the organic matter in the soil serves as a source of nutrition for many soil microorganisms. Humus is an excellent water absorbent: 1 g of humus can absorb from 4 to 20 g of water, which is returned to the plants during droughts. In the process of absorbing water and returning it, humus gets loosened, which improves the air-water conditions of the soil. Its dark colour helps the soil to intensively absorb sun rays, warming it up more quickly.

Mechanical Composition of Soil

The mechanical or granulometric composition of soil is the content of particles and mechanical elements of various sizes in the soil that remain after complete destruction of the substances and glue these particles (S.V. Zonn, 1974). The following is a classification of grounds based on the particle size:

Ground	Particle size
Rubble	>20
Chad	<20
Coarse sand	<2
Fine sand	<0.2
Loam	<0.002
Coarse dust	0.05-0.01
Fine dust	0.005-0.001
Coarse silt	0.001-0.0005
Fine silt	0.0005-0.0001

In addition to the fractions listed above, there are also colloid particles less than 0.1×10^{-6} m in size. However, in practice the subdivision of fractions is often simplified; they are divided into physical clay (particle size less than 0.01 mm) and physical sand (particle size greater than 0.01 mm). Based on the percentage of these fractions N.A. Kachinsky (1965) subdivides the soils into the groups given in Table 10.

Table 10

Classification of Soils on the Basis of Mechanical Composition (from N.A. Kachinsky)

Content of physical clay, %	Content of physical sand, %	Name of soil based on mechanical composition
0-5	100-95	Loose sand
5-10	95-90	Fixed sand
10-20	90-80	Loamy sand
20-30	80-70	Fine loam
30-40	70-60	Medium loam
40-50	60-50	Heavy loam
50-65	50-35	Light clay
65-80	35-20	Medium clay
80	20	Fine clay

Each of the enumerated fractions is characterized by specific physical properties. Mechanical elements larger than 2 mm almost do not possess capillary properties.

Sand is characterized by water permeability and high moisture content and also by capillary properties. Dust is slightly water permeable, but has high capillarity. Silt binds the soil and imparts plasticity; this fraction is practically impermeable to water and is capable of retaining a great amount of moisture.

Clayey soil has high moisture capacity and low heat conductivity. In comparison to sandy and loamy sandy soils it is richer in nutrients. It is less water permeable.

Sandy soil is poor in humus and nutrients, and it has low moisture capacity, good water permeability, good heat conductivity and low absorbability.

Loamy soil is most favourable for the cultivation of vegetables and other plants.

Loamy sandy soil has an ashy structure. It is not rich in humus and minerals. It has good water and air permeability. It requires improvement of its condition.

N.A. Kachinsky suggested the following method for the field determination of the mechanical composition of the soil. Slightly moistened soil is rolled into a string in the palm of one's hand and then it is formed into a ring. The ability of the moistened soil to form a string or a ring indicates what mechanical composition is in the following way: a string is not formed during rolling (sand); initial strings are formed (loamy sand); the string breaks during rolling (fine loam); the string is solid but breaks during rolling (medium loam); the string is solid, a ring is formed, but it has cracks (heavy loam); the string and the ring are solid (clay).

It should be mentioned that soils with sandy and loamy sandy mechanical composition are rarely found in the tropics. They possess large non-capillary pores and have a loose consistency. These soils, as a rule, require an increase in clay content and the addition of mineral and organic fertilizers. In contrast to it clayey soils are compactly packed and, therefore, are harder to cultivate. They have many capillary pores. These soils contain a large number of nutrients and if you add lime, organic fertilizers, and sand to them, they may be suitable for growing many crops.

Many tropical soils are characterized by a predominance of fine dust. They do not have enough silt capable of creating aggregates, and as a result, the aggregates of these soils are often destroyed, especially when the humus content is low. They are subject to water and wind erosion.

Loose loam, which contains enough humus and calcium (loessial and chernozem soils), is the most favourable soil for growing the majority of vegetable crops.

The mechanical composition of the soil greatly affects its structure. The structural property is the characteristic of soil to fall apart into separate pieces of different size and shape. From the agricultural point of view the most valuable soils are those with small-crumb and granular structure forming aggregates ranging in size from 0.25 to 10 mm. Structureless soil is the soil in which separate mechanical elements (sand, dust) are not connected with each other. In the structural soil normal water and air conditions are created and maintained. It is easier to cultivate structural soil.

Mineral, organic, and organomineral soil colloids are important for the formation of soil structure, because structure formation takes place under the influence of the coagulation of colloids and the glueing together of mechanical elements with colloidal films. Because of their small particle size soil colloids have a large total surface imparting a great capacity to adsorb and retain water (physical absorption) and the nutrients dissolved in it on the whole surface. Clayey and loamy soils with a large content of humus are richest in colloids, and sandy and loamy sand soils are poorest in them.

The specific mass of soil is the ratio of the mass of the solid phase of dry soil (organic and mineral matter) to the mass of an equal volume of water at 4°C. The specific mass of the organic matter of the soil ranges from 1.25 to 1.80 and the specific mass of minerals and rocks ranges from 1.58 to 5.3. Therefore, the higher the content of organic matter in the soil, the less is its specific mass. On the average, the specific mass of the majority of soils ranges from 2.50 to 2.65. The specific mass drops to 2.37 for chernozem soils, which contain 10.3 per cent of humus, and increases to between 2.8 and 3.0 for tropical ferruginous soils scarce in humus. The volumetrical mass of soil is the ratio of a specific non-disturbed volume of dry soil (with pores and wells) to the mass of water of the same volume at 4°C. It is usually expressed by a relative mass of 1 cm^3 of the soil in its natural condition. The looser and richer in humus, the better the soil's structure is expressed and the less is its volumetrical mass. The volumetrical mass of soils varies from 1 to 1.8. Usually in the arable layer of tropical soils it is equal to 1.4 and lower. Compact firm soils are characterized by a volumetric mass equal to between 1.8 and 1.9. The volumetrical mass of chernozem ranges from 1.04 to 1.10.

The volumetrical mass of the soil characterizes soil density and porosity. The soil density is the mass of a unit volume of dry soil (1 cm^3) in its natural condition. The density of the arable layer of coarse grain sandy soil is 1.8; of podzolic loamy soil, 1.2; and of typical chernozem, 1.0. Porosity is the total volume of all the pores and spaces between soil particles in a specific volume of soil. The total void content consists of the non-capillary void content, with pores 8×10^{-6} m in diameter that are filled with air after precipitation leakage, and the capillary void content, with pores less than 8×10^{-6} min diameter through which water does not drain under the force of gravity. The total void content depends on the mechanical composition and degree of structure of the soil, and the non-capillary void content is a direct function of the structure degree of the soil. The better the structure degree of soil is, the greater is the total porosity; the total void content of structural chernozem exceeds 60 per cent. The void content is reduced to 40 per cent and less in loose structureless and compact tropical soils. The void content of tropical soils is in natural conditions usually low and this necessitates their frequent and careful tillage. This is particularly necessary, when dealing with red ferralitic acid and dark compact soils. When soil is loosened, its porosity increases and vice versa.

Water in the Soil

Water in the soil functions like blood in a living organism. One of the main tasks of agronomy is to create a favourable water regimen of soils. The amount of water expressed in percentage to the mass of dry soil is called the soil humidity. Soil water exists in different states, which has varying significance for the nutrition of plants.

Gravitational water occupies the large non-capillary pores in the soil; it moves downwards under its own weight. This is the most accessible water for plants. It leaks into the deeper layers of sandy soils, it is inaccessible to roots and feeds the groundwater. The rate of water movement is expressed by a filtration coefficient, which is 0.05-0.10 m/day for medium and fine loams, 0.10-0.50 m/day for loamy sands, 0.25-0.50 for loess, 0.5-1.0 for dusty sand, and 1.0-5.0 m/day for fine grain sand.

Capillary water occupies the capillary pores. It travels from the more humid to the drier layer; it is quite accessible to plants and is the main source of their water requirement.

Hygroscopic water is in the soil in the form of molecules, arranged on the surface of separate soil fractions. It is inaccessible to plants and moves between soil fractions by diffusion.

Pellicular water is one of the forms of sorption water and lies above hygroscopic water in a thin layer. It is not accessible to plants.

Vaporous water is in the soil air in the form of water vapour and it is formed mainly by the evaporation of fluid water or it enters the soil from the atmosphere. Vaporous water is inaccessible to plants, but at low temperatures it turns into fluid water and can be used by plants.

If the stores of capillary and non-capillary water (the water that is in capillary pores) are exhausted, the plants remain without water. The soil humidity at which plants start wilting and die from the lack of water is called the humidity of stable wilting. We must note that the humidity of wilting of plants in clayey soils is higher than in sandy soils, i.e. given the same soil humidity, sandy soils contain more water that is accessible to plants than clayey soils. This is based on their different water retention capacity.

The most important index of the soil water property is the water moisture capacity, i.e. the capacity of the soil to absorb and retain an amount of water. The total moisture capacity and the limited field moisture capacity, or minimal moisture capacity, are distinguished. The state at which all the pores are filled with water corresponds to the total moisture capacity. The moistening of the soil up to 100 per cent of the total moisture capacity is a rare and fleeting phenomenon. The minimal moisture capacity is the amount of water that the soil can firmly retain under field conditions after its abundant and free draining.

The total moisture capacity indicates the maximum amount of water that the soil can take and absorb. And the minimal moisture

Table 11

Determination of Soil Humidity under Field Conditions (from J. Jenik, 1975)*

Degree of humidity	State	Field moisture capacity, %
Dry	Powdery	0
Low (critical)	Scatters and does not form clumps	25
Moderate (usually during irrigation)	Forms clumps, which crumble when tossed several times	25-50
Good	Forms clumps, which do not crumble when thrown five times and which are slightly sticky when pressed	50-75
Excellent	Forms durable clumps and is pliable when pressed; it is very sticky; when pressed hard, a big lump of soil adheres to the finger	75-100
Too humid	When a clump is pressed hard, some water may be squeezed out	Higher than field moisture capacity

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* On sandy soils with any humidity, the clumps are looser and more brittle.

capacity characterizes the maximum amount of water that the soil can retain for a long time after abundant irrigation or precipitation. The minimal moisture capacity is equal (as a percentage of the dry soil mass) to the following: sandy soils, 3-5; loamy sandy soils, 10-12; fine loamy and clayey soils, 13-22. In the humus horizon of the chernozem it may be 40-45 per cent (V.N. Prokoshev, M.N. Gurenev, 1981).

The determination of the field moisture capacity under field conditions is very important and is made possible by the J. Jenik method (Table 11). For the majority of vegetable crops the optimal soil humidity is between 60 and 80 per cent of the minimal moisture capacity (Table 12).

Soil temperature. A specific soil temperature regimen is necessary for the development of plants and the vital activity of microorganisms. The most important role of soil temperature in the life of plants is its influence on water exchange in plants. Plants extract water from warm soils more quickly and easily than from cold soils. When the temperature decreases from 20°C to 0°C, the water absorption of the roots decreases to 60-70 per cent, because the water penetrating ability of the protoplasma is reduced and root growth is inhibited. Bean, tomato, cucumber, pumpkin, and other plants from warm regions stop absorbing water at temperatures below 5°C (V. Larkher, 1978). The conditions for the water and mineral nutrition of plants worsen with cooling, as well as with overheating of the soil.

Table 12

Optimum Growing Conditions for Vegetable Crops (from A.B. Gobeev, K.V. Guber, 1980)

Name of crop	Air humidity, %	Soil temperature, °C	Soil humidity, % of minimal moisture capacity
Cabbage	50-75	13-18	80
Savoy cabbage	60-70	16-18	70-80
Brussels sprouts	60-70	16-18	70-80
Cauliflower	70-80	16-21	70-80
Turnip	60-75	12-20	65-75
Rutabaga	60-75	12-20	70-80
Tomato	45-60	20-25	70
Brinjal	50-60	20-30	80
Pepper	50-60	18-25	70-80
Cucumber	70-80	25-27	60-80
Onion	70-80	13-16	70-80
Welsh onion	70-80	13-16	70-80
Garlic	50-70	13-16	60-70
Carrot	60-70	13-16	65-75
Beet	60-80	13-16	70-80
Parsley	60-80	13-16	70-80
Celery	60-80	13-16	70-80
Parsnip	60-80	15-16	70-80

Soil temperature is also important for the germination and growth of seeds in the initial stages. The minimal soil temperature for the germination of the seeds of the major vegetable crops ranges between 0 and 15.5°C, the optimal temperature is between 20 and 35°C, and the maximum temperature is between 25 and 40°C (Table 13).

The thermal properties of soil are important for the subtropics and the highlands. It

Table 13

Temperature for Germinating Seeds of Vegetable Grops, °C (from H.T. Hartmann, D.E. Kester, 1968)*

Minimum			
0	4.4	10	15.5
Endive, lettuce, onion, parsnip, spinach	Beet, broccoli, cabbage, carrot, cauliflower, celery, parsley, peas, small radish, Swiss chard, turnip	Asparagus, sweet corn, tomato	Lima bean, kidney bean, cucumber, brinjal, melon, okra, pepper, pumpkin, winter squash, watermelon

Optimum				
21.1	24	26.7	29.4	35
Celery, parsnip, spinach	Asparagus, endive, lettuce, peas	Lima bean, carrot, cauliflower, onion, parsley	Kidney bean, beet, broccoli, cabbage, brinjal, pepper, small radish, sweet corn, Swiss chard, tomato, turnip	Cucumber, melon, okra, pumpkin, winter squash, watermelon

Table 13 (*concluded*)

Maximum			
24	29.4	35	40.6
Celery, endive, lettuce	Lima bean, parsnip, peas	Asparagus, pepper, kidney bean, beet, small radish, broccoli, tomato, cabbage, carrot, parsley, cauliflower, brinjal	Cucumber, melon, okra, pumpkin, corn, turnip, watermelon

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* At minimum temperatures seeds germinate over a longer period; at optimum temperatures, they germinate in a short period.

should be noted that dark-coloured soils are heated by the sun faster than light-coloured soils. In the spring, soils with a lower water content are heated more quickly and overmoistened soils are heated more slowly. Heat conductivity is greatest in the mineral fraction of the soil and least in the humic fraction. The more humus and air in the soil, the less is the heat conductivity of the soil and the longer its accumulated heat is retained. In contrast, structureless, compacted, and highly moistened soils poor with a low content of humus loose heat quickly. These circumstances must be taken into account when the optimal periods for vegetable sowing in the indicated zones are being determined.

Soil reaction. Since each type of soil contains a certain amount of soluble matter, it possesses a specific reaction, which is manifested during interaction with water or salt solutions. The reaction of a soil solution is determined by the concentration of H^+ and OH^- ions; it is characterized by a pH value (hydrogen-ion concentration exponent, from 0 to 14) and varies from 3 to 11 with the following acidity or alkalinity gradations:

3-4.5	Strongly acid
4.5-5.5	Acid
5.5-6.5	Weakly acid
6.5-7.0	Neutral
7.0-7.5	Weakly alkaline
7.5-8.5	Alkaline
8.5 and higher	Strongly alkaline

Different vegetable crops require different pH values of the soil solution. Accessible limits of pH values for the normal growth of different vegetable crops are given below (Table 14).

Table 14

Optimal pH Values for the Growth and Development of Vegetable Plants (from D. Raymond, 1976)

Culture	pH range
Asparagus, beet, cabbage, melon	5.9-8.0
Peas, spinach, summer squash	6.0-7.5
Celery, chives, endive, rhubarb, horseradish, lettuce, onion, radish, cauliflower	5.9-6.9
Corn, pumpkin, tomato	5.4-7.5
Bean, carrot, cucumber, parsnip, pepper, rutabaga, winter squash	5.4-6.9
Brinjal, watermelon	5.4-6.4
Potato, sweet potato	4.8-6.4

The majority of soils of humid regions have a slight acidic or neutral reaction; alkaline soils are typical for more arid regions. A significant salt accumulation may occur on alkaline soils, and this leads to their salinization. Acid soils are, as a rule, low in nutrients and structureless. Among the land resources of our planet, there are soils exhibiting different reactions. Chernozems, for example, have a neutral or weakly acidic reaction, which is favourable for the majority of vegetables, soddy podzolic soils have an acidic reaction, and peaty soils have a strongly acidic reaction (pH is approximately 3). White and black alkalies of dry areas are characterized by an alkaline reaction (V. Larkher, 1978).

High soil acidity has become the major problem for vegetable growing in many humid tropical and subtropical areas. In India, for example, about 26 million hectares of the soil have an acidic reaction (pH is below 5.6), a part of which, although a small part, has a pH value as low as 4.0 or 3.8 (S. Govinda Rajan, H.G. Gopala Rao, 1978). A well-known Indian vegetable grower, B. Choudhury (1979), classified vegetable plants into three groups according to their tolerance to acidic soils:

(1) less tolerant (pH, 6.0-6.8): asparagus, beet, broccoli, cabbage, cauliflower, celery, leaf beet, Chinese cabbage, leek, lettuce, melon, New Zealand spinach, okra, onion, and spinach;

(2) moderately tolerant (pH, 5.5-6.8): beans, Brussels sprouts, carrot, cucumber, brinjal, garlic, horseradish, kohlrabi, parsley, peas, pepper, pumpkin, radish, winter squash, tomato, and shalgam turnip;

(3) very tolerant (pH, 5.0-6.8): chicory, endive, potato, rhubarb, sweet potato, and watermelon.

Another, not less important, problem facing market gardens in tropical and subtropical areas is the soil salinization. Almost a quarter of the earth's soils is salinized to a certain extent. In India, for example, nearly 7 million hectares of farmlands are, to a certain extent, salinized (S.V. Govinda Rajan, H.G. Gopala Rao, 1978). The salinization of soils can occur in humid, as well as in arid, climatic conditions. In a humid climate, however, this occurs less often and, mainly, only when soils are moistened with groundwater rich in salts. Such salinization is often observed on sea coasts. The hot arid climate in which evaporation exceeds precipitation causes the rising water run, which is rich in salts. As to the ratio of salinizing ions (sodium, chlorine, sulphate, and carbonate) in the soil, the following types occur (Ye.P. Alyoshin, A.A. Ponomaryov, 1979): sulphate-chloride salinization (maritime) is observed in the coastal lowlands of river deltas and on coasts; chloride-sulphate salinization (continental) is observed in Eastern Africa, Mexico, and in the river valleys of Asia, Southern Europe, Northern Africa, and America; sodium salinization is rarely seen, these salts have a pH of 11 and are found in the river terraces of the monsoonal tropics of Asia, the steppes of Australia, the savannahs of Africa, and the pampas of Latin America.

It should be mentioned that among the basic salts that salinize soils, the very easily-soluble salts ($NaCl$, $MoCl_2$, and $CaCl_2$) are most harmful, and the sparingly soluble salts ($CaSO_4$, $MoSO_4$, and $CaCO_3$) are less toxic. Salts are harmful to plants mainly because of their osmotic and specific, or toxic, effect on the metabolic processes of the cell. The osmotic effect is explained by the fact that salt solutions bind water and increase its concentration. An increased concentration of salts makes the water less accessible to plants and, therefore, more effort must be expended to absorb it.

In 1961, J. S. Kanvar (quoted from S. V. Govinda Rajan, H.G. Gopala Rao, 1978) divided vegetable crops into the following three groups according to their salt tolerance:

1. Sensitive crops: celery.
2. Moderately resistant crops: tomato, cabbage, cauliflower, lettuce, potato, carrot, onion, peas, cucumber, pumpkin, and corn.
3. Resistant crops: turnip, beet, radish, and spinach.

Any classification of plants based on salt tolerance is, however, conditional and determined more precisely in every region, on different soils. Other characteristics specific to the climate and the soils of cultivation area also have an influence on the salt tolerance of plants. V. Larkher (1978), for example, in contrast to the data given above, classifies peas, potato, bean, and radish as very sensitive plants.

The salt tolerance of plants also depends on their stage of development. In the initial stages plants are more sensitive to salinization than in the later stages. Many authors note that salt tolerance is lower at the stage of blossoming and fruit formation. Therefore, at these stages, the measures taken to control soil salinization, by irrigation or draining, and the timely application of organic fertilizers, are particularly important.

The soil reaction has an influence on the availability of nutrients and on certain processes that take place in soils (Fig. 4): in

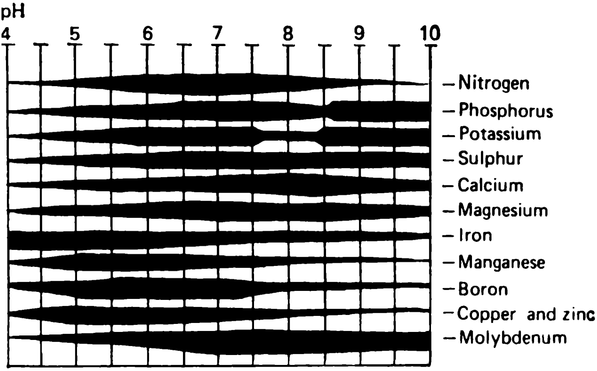

Figure 4
Availability of nutrients depending on the soil reaction (the wide part of the band shows maximum availability)

acid soils, in particular, the availability of major elements (N, P, K, S, Mg, and Ca) and of the trace element molybdenum is decreased. A deficiency of zinc, manganese, iron, and copper is often observed in soils exhibiting an alkaline reaction and the optimum content and availability of all the major and trace elements are observed in weakly acidic and neutral soils. These problems must be considered when crops are supplemented with fertilizers.

Nutrients and Their Influence on the Growth and Development of Plants

The basic nutrients for plants are divided into macronutrients, which the plant requires in large quantities (N, P, K, S, Ca, Mg, C, H, O, and Na) and micronutrients, which are required in small quantities (B, Mn, C, Zn, Mo, Cl, and Co). Iron is on the borderline between the macro- and micronutrients. Such a classification is conditional as far as the requirements of different plant varieties vary and depend on the conditions of the cultivated area and the stage of development. Nitrogen, phosphorus, potassium, calcium, and magnesium are the most important nutrient elements. Nitrogen is necessary for the vegetative growth of plants; phosphorus is necessary for root growth and fruit formation; and potassium, for reproductive development. Potassium does not enter into the organic compounds of plants. It is mostly contained in those organs and tissues where a high rate of carbohydrate metabolism is maintained and intensive cell division occurs. However, the mechanism of interaction and mutual influence of these elements on plants is large and diverse. An abundance, as well as a shortage, of mineral nutrients, has negative consequences for plants. The effects of shortages of specific nutrients are represented in Table 15.

Nutrient requirements for vegetable plants. Vegetable crops have exceptional nutrient requirements, which is explained by their high productivity and the removal of nutrients with the yield. Based on the removal of nutrients, vegetable crops are divided into four groups: crops with high removal, for example, cabbage, celery, and kohlrabi; crops with moderate removal, e.g. tomato, onion, asparagus, potato, and carrot; crops with low re-

Table 15

Symptoms of Nutrient Deficiency in Soil

Nutrient	Symptoms
Nitrogen	Light green plant, small- or dwarf-sized, premature yellowing of the lower leaves. New leaves of light green colour with red veins, leaves are narrow
Phosphorus	Dark green plant, blossoming delayed and growth absent, leaves are bronze-violet, root system is weakly developed
Potassium	Tops are dried, edges of leaves are twisted, necrotic spots are at the tops and between veins, plant looks withered (water balance is disturbed)
Calcium	Stem is brittle, top is dry, new leaves are brittle and twisted, blades are whitish-green in colour, sometimes light brown or brown spots appear on the leaves
Magnesium	Leaves are chlorotic, speckled, and, in some cases, red (with necrotic spots), chlorosis is observed in older leaves, they have thin stems
Sulphur	Similar to the symptoms of nitrogen starvation
Iron	Intervein chlorosis of new leaves, sometimes leaves are decoloured, but the veins are green
Boron	Young leaves are light green and hooked, production of fruits is impared because of barren flowers and falling off of reproductive organs
Zinc	Leaves are thick, with numerous spots, internodules of stems are shortened, rosette growth

Table 15 (*concluded*)

Nutrient	Symptoms
Copper	Withering of tops, chlorosis of new leaves
Molybdenum	Impairment of growth, deformation of shoots, light colouring of plants
Manganese	Necrotic spots covering the whole area of the leaf

moval, e.g. lettuce and spinach; and crops with very low removal, e.g. small radish and cucumber.

Vegetable crops are also distinguished by their high removal of a specific element from the soil. For example, beans, cabbage, and small radish absorb more nitrogen; radish, cabbage, and cucumber are characterized by a high removal of phosphorus; and cabbage, carrot, tomato, and potato are distinguished by a high removal of potassium.

As has already been mentioned, nitrogen, phosphorus, and potassium affect plants differently. Nitrogen increases the biomass, and phosphorus increases the specific weight of the root system in the whole biomass. Therefore, leafy vegetables (cabbage, lettuce, spinach, and sorrel) require more nitrogen, and root crops, more potassium, and fruit-bearing (tomato, cucumber, etc.), more phosphorus.

The Regulation of Environmental Conditions in Home Garden Vegetable Growing

The growth, development, and productivity of plants are closely connected with the environment. Since time immemorial mankind has tried to actively influence the environment in order to create optimum conditions for plants. The regulation of environmental conditions on an industrial scale with the commodity production of vegetables is a labour-consuming, and sometimes unprofitable, activity. This task is made easier with small home gardens because of their limited size. If in commodity vegetable growing the problem is solved mainly by cultivating the varieties fit for a given locality, in home gardening it is extremely important to create those conditions in which a particular variety could thrive.

Regulation of air temperature. In agricultural practice damage to plants due to overheating occurs rarely. Damage is most often caused by cold weather and frosts. In the plains of tropical zones frosts rarely occur, but tropical plants can be heavily damaged even at temperatures above zero. This danger increases with altitude and when approaching subtropical areas. Frosts occur relatively often in subtropical areas.

Today, science has developed many ways for fighting frosts. The most widespread among them are separate caps and film coverings (mostly tunnels) made of various materials (glass, polyethylene, polyamide, polyvinylchloride films, cardboard, and paper), sprinkler irrigation, fogging, covering with stable foam (using foaming agents), and the artificial shift of cold air layers. The first two methods are widespread in home garden vegetable growing.

Separate caps for the protection of plants from light frosts lost their significance in industrial vegetable production, because their application is labour intensive. In home garden vegetable growing, however, they are quite acceptable and simple in design. Glass, paper, or film can serve as covering material. On hot sunny days the caps are half opened. Their height depends on the growth rates of the plants and on the length of time that the plants must be covered. As the plants grow, holes are cut out at the top and when the weather is stable and warm, the caps are completely removed. This method is used for the short-term covering of plants during the initial stages of growth.

Film tunnels. This is a widespread type of covering. A film, 120-180 cm wide, serves as the covering material. Wire arcs or twigs form a support for the film. They are arranged over the plants at a particular distance from the plants and from each other (Fig. 5). Then the film is stretched over them and is covered with earth on the side of the prevailing winds. The other free side is used for ventilation. When the weather becomes warm, the covering is removed. With careful handling, the film can be used two or three times. The film can also be used for mulching. Sometimes, the

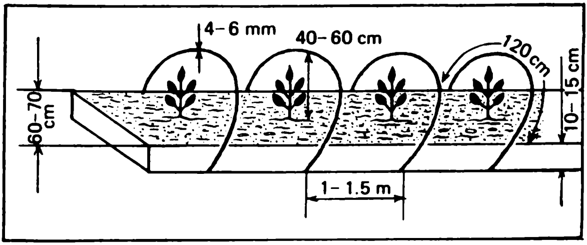

Figure 5
The location of arcs for polyethylene tunnel coverings

plants are covered with perforated (drilled) film so that it is not necessary to ventilate them. The number of holes per 1 sq m punched in the film depends on the specific features of the climate and grown crop. Most often it is from 50 to 100 holes per square metre are required.

This type of covering reduces the danger of frost damage and improves the temperature regimen of the soil and air, which speeds up the growth and development of the plants and increases their productivity. In areas where late spring frosts occur, the application of coverings allows the early planting of vegetable seedlings and results in high early harvests. The time saved by early planting can be used for growing another crop. Under the coverings seedlings of more heat-loving crops can be grown which are then moved to open ground.

Mulching. An insulating material, scattered on the soil surface, is called mulch. There is intercrop and continuous mulching. Film-like material, mulch paper, peat crumb, compost, manure, mull earth, straw, sawdust, and even fallen leaves and post-harvesting remains can serve as mulch. Mulch preserves soil water through the decrease in soil temperature and evaporation of water from its surface. Different temperature conditions are created under different kinds of mulches. Light mulch decreases soil heating in the daytime and dark mulch increases it. In the tropics and subtropics, mulching is conducted mainly during the intensive growth period of plants. Mulch is applied in order to preserve water, suppress the growth of weeds, and provide plants with sufficient nutrients. Weeds are best suppressed under a dark mulch where there is less light. Additional nitrogen fertilizers may yield good results in mulching. Mulching is particularly effective under arid conditions.

Among the indirect methods of fighting frosts and regulating temperature are agrotechnical methods that promote heat accumulation in the daytime and prevent its loss to the atmosphere at night. These include cultivation, irrigation, fogging, and foaming.

The regulation of lighting in vegetable gardens of the tropics and subtropics is rarely used. In many cases, however, when the plants are located and formed, this factor is taken into account during the planting and growth of crops.

The arrangement of rows also influences the quantity, intensity, and duration of the solar radiation falling on a plant. Rows oriented from east to west use light more effectively than those oriented from north to south where one row can shade another. However, the steepness of the area, the direction and strength of the wind, and the methods of growing plants play a decisive role in determining the orientation of the rows. In tropical areas the protection of fruit from solar burns is of great importance. Various shading devices and reflecting materials are used to protect against such burns. To get tender, juicy, and, sometimes, bleached above-ground parts, the plants are either shaded or the specific parts are covered with various materials and soil.

Methods for Increasing Soil Fertility

The main economical factor that limits the growing of vegetables in tropical and subtropical areas is the soil. The soils of these regions are, as a rule, scarce in available nutrients and, sometimes, due to high salinity or excess acidity, they are not fit for agriculture. Because of the specific climatic characteristics, the majority of tropical soils are destroyed and subject to water or wind erosion. Therefore, in spite of the rich climatic resources in this area, vegetable growing is limited by the low fertility of the soil. Fertility is defined as the ability of soil to provide the plants with the nutrients necessary for their growth and development and the optimum quantity of water and air. Soil fertility depends directly on the physical, chemical, physicochemical, hydrothermal, and biological properties of the soil. All these factors are, to a certain extent, subject to regulation. Hence, the increase in soil fertility is man's handiwork.

The majority of tropical and subtropical soils have a low content of humus, which is the consequence of its quick year-round mineralization under the influence of tillage and favourable weather conditions. The solum depth of their humus horizon is, as a rule, 14-20 cm. As was mentioned before, soils rich in organic matter possess a number of other valuable properties such as high moisture retention capacity, improved structure, favourable nutritive regimen, and a high concentration of carbon dioxide in the soil air.

The content of organic matter in the soil may be increased by dunging, application of mull earth, compost (village and town), and green manure at the expense of green manure crops. Enrichment of the soil with humus is especially important when growing vegetables, because these crops leave little plant debris and remove a large amount of nutrients. In tropical and subtropical areas where the indoor maintenance of animals is rare, there is shortage of manure and, in addition, in many countries dry manure is used as fuel. The main organic fertilizers in the home garden vegetable growing of tropical and subtropical areas are compost (a mixture of soil with different kinds of decaying organic matter) and green manure. However, the use of green manure is effective only during irrigation, because it decays quickly and intensively only at the corresponding humidity. For these purposes green manure crops are grown in succession cropping either as an intermediate crop or mixed with vegetable crops. Leguminous plants (nitrogen fixers) are mainly used for green manure management. They enrich the soil with available nitrogen and their well-developed root system improves soil structure.

Compost is the most effective and accessible organic fertilizer that can be used in home garden vegetable growing. Compost can be prepared by market gardeners themselves in various containers, but compost pits and piles are most common (mainly in rural areas). Pits are dug in a shaded corner of a vegetable garden. All the garbage and waste matter, including ash, is thrown into the pit. A pile is a more convenient receptacle for compost. The compost pile is prepared with alternating layers of soil or sod and organic waste (manure, garbage, chaff, etc.). Sometimes, lime and mineral fertilizers are added to the mixture (to regulate the pH value), which speeds up compost decay. Sometimes, water is added to the mixture and the pile is turned over. Compost is ready for use after several weeks when it can be scattered over the plot. Sometimes, compost is mixed with soil 15-20 days before sowing or planting.

Peat soils are dark and heavy and, as a rule, they have an acidic reaction (pH is 3-4). They contain from 10 to 40 per cent organic matter and are deficient in available phosphorus. The acidic reaction of these soils is connected with the decay of organic matter under anaerobic conditions. Sometimes, because of the high content of ammonium sulphates and iron, they are toxic to plants. In the tropics these soils are used mainly for growing rice under flooded conditions (S.P. Raychaudhuri et al., 1963). However, with artificial drainage these soils may also be used for vegetable crops. During draining, air reaches the peat horizon, oxidation takes place, and the peat turns into mull earth. Humic soils are most productive and in many countries they are used as fertilizer.

The soil reaction is an important factor that influences the availability of nutrients and the growth of roots. The majority of vegetable crops grow and develop well with the pH of approximately 6-6.8. Soils with very low pH values (acidic, peaty, etc.) or with very high pH values (alkaline, salinized) are often found in nature. It is impossible to obtain high yields on such soils without decreasing or increasing their acidity.

The pH value of strongly acid soils is usually increased by the application of lime. Disintegrated chalked rock is frequently used. It mainly consists of $CaCO_3$ and sometimes of a small quantity of $MoCO_3$. It is necessary to bear in mind that different soils and crops react differently to chalking. The quantity of lime depends on the mechanical composition of the soil and on its original acidity. If the pH value of a soil solution is below 5.7, lime application increases the yield of mature crops. If it is even lower, 1-2 tons of lime per hectare should be applied. At a lower pH level the amount of lime applied should be increased. Lime is best applied one year before the crop requiring it is sown, and the lime should be mixed with the soil.

Soil acidification is rarely encountered in agricultural practice. It is required when separately growing vegetable crops that prefer an acidic soil medium. The application of sulphur or sulphides results in lower pH values. Sometimes, acidification is accomplished by using acidifying nitrogen fertilizers, which contain ammonia, for several years.

4

The Species Composition of Vegetable Crops Cultivated in Home Gardens of Tropical and Subtropical Areas

About 300 000 plant species are known to science and many more thousands of them have not yet been described and named (N.Bubell, 1979). Carolus Linnaeus, the founder of the taxonomic classification of plants, who lived in the 18th century, described nearly 10 000 plant species (P.M. Zhukovsky, 1964). More than 2500 species lie within the sphere of human activity. Ninety-nine per cent of the cultivated land surface is occupied by 1000 species (Yu.P. Laptev, 1980). I.I. Sinyagin (1968) notes that in the temperate zone plants belonging to 18-20 botanical families are cultivated. In tropical areas of the globe because of the specific climatic conditions approximately 300 species belonging to 69 families (not counting medicinal and wild plants) are used. Botanists know of more than 2500 species of wild medicinal plants. Nowadays, only between 150 and 200 species are used for making medicinal preparations. It is obvious that the huge variety of plants given to us by nature are far from completely utilized. Many of these plants are vegetable crops. The cultivation of these plants must start with the vegetable garden.

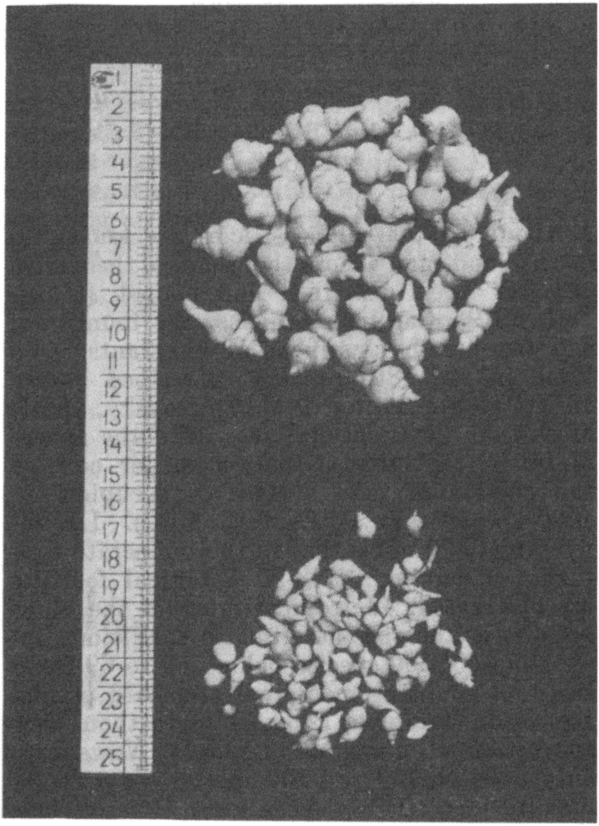

Figure 6
Tubers of chinese artichoke

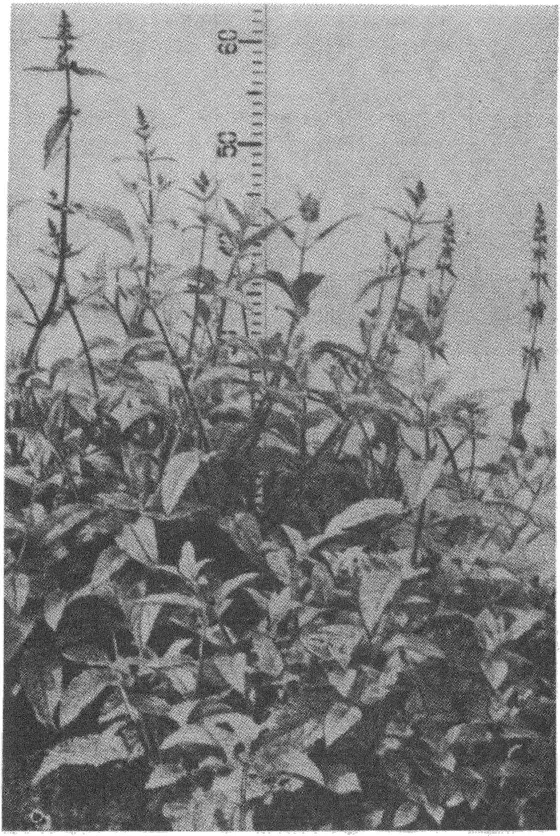

Figure 7
Chinese artichoke whose young leaves are used as food

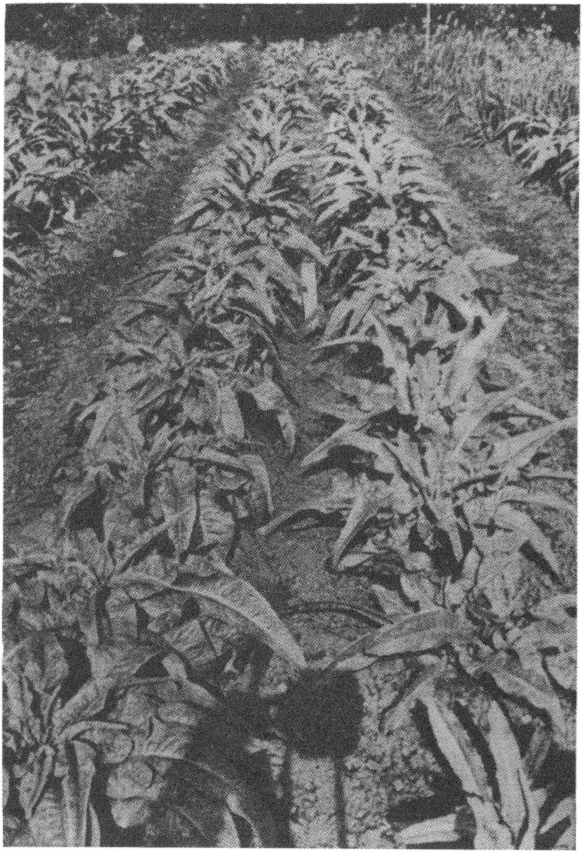

Figure 8
Asparagus type at the stage of using young leaves as food

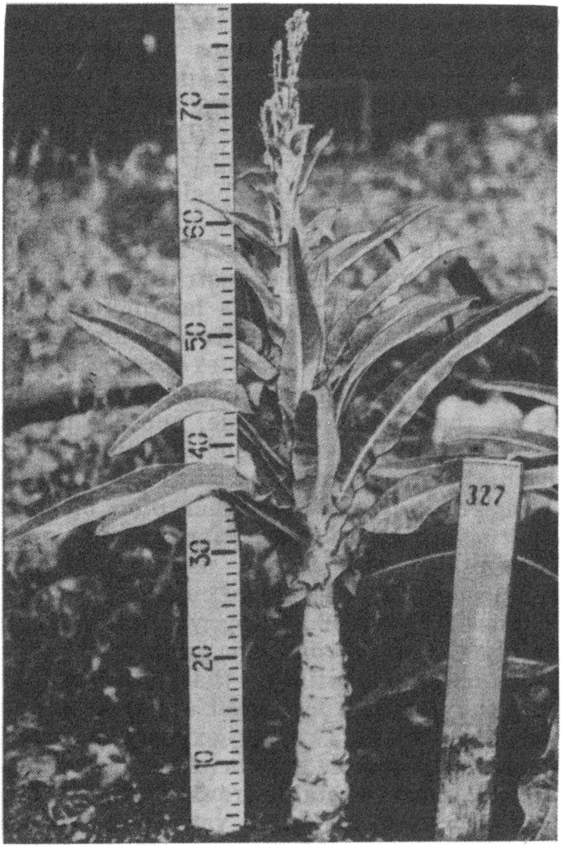

Figure 9
Asparagus type at the stage of industrial ripeness of stems (for salting and other uses)

According to specialists vegetable plants consist of 1200 species from 78 families. Among them, dicotyledonous plants prevail, constituting more than 860 species belonging to 59 families. The remaining 19 families are monocotyledonous plants (D.D. Brezhnev, P. F. Kononkov, 1977).

Six hundred vegetable species are cultivated by vegetable growers of all the countries of the world (A. N. Strizhev, 1980), but vegetable growing by large industries deals with a limited number of crops (a maximum of 10-15). In the tropical and subtropical areas of the globe approximately 90 species of vegetables are cultivated. The main species of vegetable plants, their botanical name, and the part of the plant that is used as food are given in Table 16. Only some of these crops are, however, widely cultivated in the garden plots of developing countries. In Sudan, for example, about 70 vegetable species are used as food; in India, about 90 species are cultivated; and in Pakistan, about 50. Many vegetable plants, mainly the spicy ones, are gathered.

It should be mentioned that in many countries the largest portion of nutrients are obtained, as a rule, at the expense of a small amount of vegetable plants (often from 5 to 10 species). Many vegetable growers in these countries grow only a limited variety of crops on their plots, because they are not informed about the high productivity and high nutrient value of vegetables, the specific features of plant biology and farming, and the huge diversity of vegetables. That is why the majority of the

Table 16

Vegetable Crops Cultivated in the Tropics and Subtropics

English name	Latin name		Edible part
	Family	Species	
		1. Cabbages	
Cabbage	Cruciferae (Brassicaceae)	Brassica oleracea L. var. capitata	Large terminal bud
Kale	Ditto	B. oleracea L. var. acephala (Dc.) Alef.	Leaves
Chinese cabbage	Ditto	B. Chinensis L.	Long leafy cabbage heads
Pekin cabbage	Ditto	B. Pekinensis (Lour.) Rupr.	Leaves and cabbage heads
Cauliflower	Ditto	B. oleracea L. var. botrytis L.	Rooted flower stem, head
Broccoli	Ditto	B. oleracea L. var. italica Plenck.	Underdeveloped flowers
Brussels sprouts	Ditto	B. oleracea L. var. gemmifera D.C.	Axillary buds or heads
Kohlrabi	Ditto	B. oleracea L. var. gongylodes L.	Aboveground thickened stem

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
		2. Root crops	
Carrot	Umbelliferae (Apiaceae)	Daucus carota L.	Roots
Beet	Chenopodiaceae	Beta vulgaris L.	Ditto
Radish	Cruciferae (Brassicaceae)	Raphanus sativus L.	Ditto
Small radish	Ditto	Raphanus sativus L. var. sativus Mansf.	Ditto
Turnip	Ditto	Brassica rapa L.	Roots and, sometimes, leaves
Rutabaga	Ditto	Brassica napobrassica (L.) Rchb.	Roots
Horseradish	Cruciferae (Brassicaceae)	Armoracia rusticana (Lam.) Gaertn.	Roots and, sometimes, leaves
Parsnip	Umbelliferae (Apiaceae)	Pastinaca sativa L.	Roots and young leaves
Celery	Ditto	Apium graveolens ssp. sativum L.	Roots, stalks or leaves

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
Parsley	Umbelliferae (Apiaceae)	Petroselinum crispum (Mill.) Nym.	Roots and leaves
Sea kale	Cruciferae (Brassicaceae)	Crambe tatarica Busch.	Roots, young shoots, and leaves
		3. Root crops and tuberous crops	
Cassava, Tapioca, Manioc	Euphorbiaceae	Manichot escutenta Crantz	Tubers and young leaves
Sweet potato	Convolvulaceae	Ipomea batatas (L.) Lam.	Tubers and, sometimes, young leaves
Colocasia, eddoes, cocoyam	Araceae	Colocasia esculenta Schott.	Tubers and, sometimes, leaves
Yams, greater	Dioscoriaceae	Dioscoria alata L.	Tubers
Irish potato	Solanaceae	Solanum tuberosum L.	Ditto
Suran, Elephants foot, yam	Alliaceae	Amorphophallus campanulatus Blume	Ditto
Chinese artichoke	Labiatae (Lamiaceae)	Stachys siebeldi Mig.	Tubercles (Fig. 6) and young leaves (Fig. 7)

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
		4. Onions	
Onion	Alliaceae	Allium cepa L.	Bulbs, sometimes, leaves
Leek	Ditto	Allium porrum L.	False stems and leaves
Garlic	Ditto	Allium sativum L.	Bulbs, flower stalks, sometimes greens
Welsh onion	Ditto	Allium fistulosum L.	Bleached stems and leaves
Shallot	Ditto	Allium ascalonicum L.	Young bulbs and leaves
Multiplier onion	Ditto	Allium fistulosum var. viviparium Macino	Leaves, root and above-ground bulbs
Chives	Ditto	Allium schoenoprasum L.	Tender green leaves
Onion, aromatic	Ditto	Allium odorum L.	
		5. Fruity vegetables	
Cucumber	Cucurbitaceae	Cucumis sativus L.	Fruits and seed oil
Pumpkin	Ditto	Cucurbita moschata Duch.	Fruits and, sometimes, young loops
Squash, winter	Ditto	Cucurbita maxima Duch.	Fruits

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
Squash, summer	Cucurbitaceae	Cucurbita pepo L.	Fruits
Muskmelon	Ditto	Cucumis melo L.	Ditto
Watermelon	Ditto	Citrullus lanatus (Thumb.) Mans.	Ditto
Scallop squash	Ditto	C. pepo var. patisson	Ditto
Choko, chayote	Ditto	Sechium edule (Jacav.) Sw.	Fruits and roots
Bittergourd, Balsam pear	Ditto	Momordica charantia L. M. balsamina L.	Green fruits
Ditto	Ditto	M. tuberosa Cong.	Fruits and tubers
Ditto	Ditto	M. dioica Roxburdh	Ditto
Ash gourd, wax gourd	Ditto	Benincasa hispida (Thumb.) Cogn.	Green fruits
Sponge gourd	Ditto	Luffa cylindrica Roem.	Young fruits
Ridge gourd	Ditto	Luffa acutaugula Roxb.	Ditto
Bottle gourd	Ditto	Lagenaria siceraria (Molina Standl.)	Green fruits, sometimes, young stems and leaves for medicinal purposes
Snake gourd	Ditto	Trichosantes anguina L.	Green fruits

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
Pointed gourd	Cucurbitaceae	Trichosantes dioica Roxb.	Green fruits
Squash melon, round gourd	Ditto	Citrullus vulgaris Schrad. var. fistulosus	Green fruits like vegetables
Tomato	Solanaceae	Lycopersicon esculentum Mill.	Fruits
Pepper	Ditto	Capsicum spp.	Ditto
Brinjal	Ditto	Solanum melongena L.	Ditto
Husk tomato	Ditto	Physalis pubescens L.	Ditto
Pepino	Ditto	Solanum muricatum Ait.	Ditto
Peas, garden	Ditto	Pisum sativum L. subsp. hartense	Seeds and blades
Peas, field	Ditto	Subsp. arvense	Ditto
String, French, kidney or common bean	Ditto	Phaseolus vulgaris L.	Ditto
Hiacinth bean, Bonavist	Ditto	Dolichos lablab (Roxb.) L.	Ditto
Chickpea, gram	Ditto	Cice arietinum L.	Ditto
Cow pea	Ditto	Vigna sinensis Savi	Ditto

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
Cluster bean	Leguminosae (Fabaceae)	Cyamopsis tetragonoloba L. Taub.	Seeds and blades
Lima bean	Ditto	Phaseolus lunatus L.	Ditto
Broad bean, horse bean	Ditto	Vicia faba L.	Ditto
Soya bean	Ditto	Glycine max. L.	Ditto
Runner bean	Ditto	P. colcineus L.	Ditto
Tepary bean	Ditto	P. acutifolius Gray.	Ditto
Mung bean, grun gram	Ditto	P. aureus Roxb.	Ditto
Pigeon pea, Congo pea	Ditto	Cajanus cajana (L.) Millsp.	Ditto
Sword bean	Ditto	Canavalia gladiata (Jycav.) DC.	Seeds and beans
Scarlet bean	Ditto	P. multiflorus Willd.	Ditto
Velvet bean	Ditto	Szirololobium Deerengianum	Ditto
Sweet corn	Craminae (Poaccea)	Zea mays L. var. rugosa	Green fruits
Okra	Malvaceae	Hibiscus esulentus L.	Young ovaries and fruits

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
Fenugreek	Fabaceae (Leguminosae)	Trigonella foenum graecum L.	Leaves and young beans
		6. Leafy vegetables	
Lettuce	Compositae (Asteraceae)	Lactuca sativa L.	Leaves
Head type		L. sativa L. var. capitata L.	Leaf heads (Fig. 7)
Leaf type	Ditto	L. s. var. crispa	Leaves
Romain type	Ditto	L. s. var. longifolia Lam.	Long loose oval semihead
Asparagus type	Ditto	L. s. var. asparagina	Young leaves (Fig. 8) and thick young stems (Fig. 9)
Endive	Ditto	Cichorium endivia L.	Leaves
Chicory	Ditto	Cichorium inthybus	Leaves or heads
Chervel	Ditto	Anthriscum cerefolium	Greens
Watercress	Cruciferae (Brassicaceae)	Nasturtium officinale L.	Leaves and tops of young shoots
Cress, land	Ditto	Lepidium sativum L.	Leaves and young shoots
Beet Leaf, Indian spinach	Chenopodiaceae	Beta vulgaris L. var Beugalensis	Tender, juicy leaves, sometimes, seed bearers

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
Swiss chard	Chenopodiaceae	Beta vulgaris L. var. Cicla	Large leaves and wide pulpy cuttings
Spinach	Ditto	Spinacea oleraceae L.	Rosette of leaves
Fenugreek	Fabaceae (Leguminosae)	Trigonella foenumgraecum L.	Leaves, young beans as vegetables, and seeds as condiment
Mustard	Cruciferae (Brassicaceae)	Brassica Juncea	Leaves and tender stems
White mustard	Ditto	Sinapis alba L.	Young shoots, leaves, and seeds
New Zealand spinach	Alzoaceae	Tetragonia expansa	Young leaves and tops of young shoots
Buckwheat	Polygonaceae	Fagopyrum tataricum Gearth	Periodically removable tender tops
Sorrel	Ditto	Rumex vesicarius L.	Leaves
French orach or spinach	Chenopodiaceae	Artiplex hortensis L.	Ditto
Amaranth	Amaranthaceae	Amarantus spp.	Ditto

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
Portulaca	Portulacaceae	Portulaca oleraceae L.	Juicy shoots and leaves
Malabar nightshade or Indian spinach	Basellaceae	Basella rubra L.	Juicy stems and leaves
Jute	Tiliaceae	Corchorus Olitoris L.	Young leaves
Black nightshade	Solanacea	Solanum nigrum L.	Young leaves and berries
Indau	Brassicacea	Eruca sativa Lam.	Leaves and stems
Dill	Umbelliferae	Anethum graveolens	Young leaves and stems
Anise	Ditto	Anisium vulgare	Fresh leaves
Caraway	Ditto	Carum Carvi L.	Ditto
Basil, sweet	Labiatae (Lamiaceae)	Ocimum basilicum L.	Ditto
Borage	Boraginaceae	Borago officinalis L.	Fresh leaves
Coriander	Umbelliferae (Apiaceae)	Coriandrum sativum L.	Leaves and seeds
Fennel, sweet	Ditto	Foeniculum Vulgare Mill.	"Small heads", early shoots and roots
Summer savory	Labiatae (Lamiaceae)	Saturejy hortensis	Fresh leaves
Lavender	Ditto	Lavandula	Flowers

Table 16 (*continued*)

English name	Latin name		Edible part
	Family	Species	
Lemon balm	Labiatae (Lamiaceae)	Melissa officinalis L.	Leaves
Oregano	Ditto	Origanum vulgare L.	Ditto
Sweet marjoram	Ditto	Majorana hortensis Moench.	Ditto
Peppermint	Ditto	Mentha piperita L.	Leaves and early shoots
Spearmint	Ditto	Mentha viridis L.	Ditto
Rosemary	Ditto	Rosmarinus officinalis L.	Ditto
Sage	Ditto	Salvia officinalis L.	Leaves
Terragon	Compositae (Asteraceae)	Artemisia dracunculus L.	Leaves and early shoots
Thyme	Labiatae (Lamiaceae)	Thymus vulgaris L.	Leaves
Hyssop	Ditto	Hyssopus officinalis L.	Leaves and raceme
Salsify	Compositae (C. Leguliflorea)	Scorzonera hispanica L.	Leaves and, mainly, roots

Table 16 (*concluded*)

English name	Latin name		Edible part
	Family	Species	
	7. Perennial vegetables		
Asparagus	Liliaceae	Asparagus officinalis L.	Early tender shoots
Artichoke, globe	Compositae (Asteraceae)	Cynara Scolymus L.	Pulpy peduncles and wide juicy bases of outer scales of wrapping of racemes
Jerusalem artichoke	Ditto	Helianthus tuberosus L.	Long tubers
Sea kale	Cruciferae (Brassicaceae)	Crambe maritima	New leaves and shoots
Catran, crambe	Ditto	Crambe tatarica Busch.	New leaves, shoots and roots
Horseradish	Ditto	Armoracia rusticana (Lam.) Gaertn.	Fresh roots, sometimes, leaves during salting
Rhubarb	Polygonaceae	Rheum raponticum L.	Large pulpy cuttings of leaves
Sorrel	Ditto	Rumex vesicarius L.	New leaves

population of tropical and subtropical areas eat monotonous, traditional food which results in a vitamin and mineral deficiency.

Selection of Vegetable Crops

The species composition of vegetable crops grown on home garden plots in tropical and subtropical countries depends more frequently on the following factors: the size of the plot, the traditional diet, the preference of the vegetable grower, the market demand, the crop productivity, the efficiency of growing the specific crop, the climatic conditions, and the season of cultivation. When, for example, the area of a plot is a limiting factor, preference is given to crops that are difficult to find in the market (celery, parsley, broccoli, etc.), to those that perish quickly (spinach, lettuce, mint, bean, and peas), or to those that give a maximum yield of the edible portion in a minimum area (tomato, beans, summer squash (Cucurbita pepo), and broccoli). For such crops as sweet corn, peas, winter squash (Cucurbita maxima), and watermelon, large growing areas are required because of the relatively low output yield. For example, the area required for growing two or three huge pumpkins is sufficient to provide an average family with vegetables, if crops such as root crops, lettuce, cabbage, pepper, or tomato are grown (J.R. Baggett, 1976). If the area of a plot is large, it is better to grow potato, sweet potato, onion, and colocasia.

Vegetable crops can also be divided into two groups based on how labour-intensive their cultivation is: labour-intensive plants are broccoli, cucumber, watermelon, and celery; nonlabour-intensive plants are corn, bean, peas, tomato, and pumpkin. The latter can be recommended to the beginner.

The major task of any vegetable grower is to get the maximum output of various vegetables over a prolonged period of time. This can be achieved by using mixed sowing and intermediate crops.

Mixed sowing of vegetable crops is widely used in agricultural systems of the tropics and subtropics. Vegetable crops are often seen in the spaces between the rows containing the main crop (rice, manioc, yams, sweet potato, colocasia, soya, potato, sorghum, etc.). If the major crops mainly serve as a source of required energy, the vegetables supplement the diet with vitamins and minerals. This is particularly important for developing countries where the nutritional value of food is at a very low level. Mixed sowing also has many advantages, as follows:

1. Mixed sowing allow the more efficient utilization of the agricultural, climatological, and soil resources of the given area.
2. By growing mixed crops, the yield does not decrease but, sometimes, even rises, i.e., the maximum yield per area unit is achieved.
3. In case of unfavourable weather conditions one crop can, to a certain extent, compensate for the damage inflicted on another crop.

4. Proper selection of crops can decrease the damage done to plants by pests and diseases and, sometimes, can even completely exclude such damage.

5. In mixed sowing less weeds are observed. The compactness of planting suppresses the growth of weeds.

6. Mixed sowing improves soil structure and prevents its erosion.

This method is widely used in the countries of Africa and Latin America, where, according to the most recent data, 40-50 per cent of the manioc and soya are grown in mixed sowing. These figures are somewhat lower in the countries of Southeast Asia, where the main food crop is floodable rice which cannot be grown in mixed sowing. A large amount of work is being done to discover the best components for mixed sowing. The selection of such mixed sowing depends on various factors, of which the major ones are: the duration of the vegetative season, the rate of the growth and development of crops, the sensitivity to environmental conditions, and the compatibility of crops. Only the correct scientific observation of these rules will result in a definite success. Let us consider each of these factors separately.

Length of the Vegetation Period

Vegetable crops differ considerably according to this index. The vegetation period of vegetable crops is from 20 days to 2 or 3 years (Table 17). In Ethiopia, for example, the vegetable crops that ripen first are radish, tur-

Table 17

Vegetation Period for Some Vegetables in the Eastern Part of Ethiopia (from Haile Mariam, 1969)

Crop	Vegetation period (days)
Artichoke	Perennial
Asparagus	Perennial
Bean	50-65
Beet	55-85
Broccoli	70-90
Brussels sprouts	90-100
Cabbage	65-110
Chinese cabbage	70-95
Carrot	65-95
Cauliflower	60-90
Celery	150-200
Cucumber	56-75
Brinjal	70-95
Garlic	70-95
Leek	110-140
Lettuce	45-90
Mustard	50-60
Onion	100-120
Parsley	70-80
Peas	54-74
Pepper	60-100
Potato	75-100
Pumpkin	115-145
Radish	23-55
Spinach	60-65
Winter squash	75-140
Corn	66-105
Swiss chard	60-75
Tomato	60-120
Turnip	45-65
Watermelon	95-115

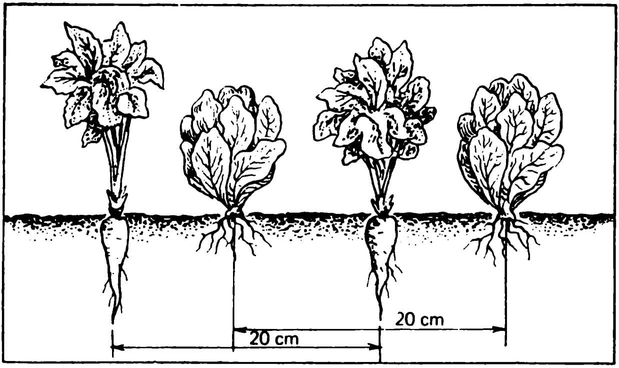

Figure 10
The growing of two cultures in one row: seeds of lettuce and parsnip (3-4) are sown in alternating clusters making rows; after the shoots appear the rows are chopped to the point when only one plant remains in a cluster. Lettuce is the first to be harvested letting the parsnip grow till the full forming of root crops

nip, carrot, and various lettuces. The vegetable plant that ripens before any others is land cress, which can be eaten 10-15 days after sowing. This fast-ripening property of various vegetables may be exploited in mixed and intermediate sowings. These vegetables can be grown between the rows, or in one row with late-ripening vegetable plants maintaining spaces between the rows (Figs. 10 and 11).

The diagrams suggested by F. Larckom (1978) are also applicable, because, along with the fast-ripening property, the root systems

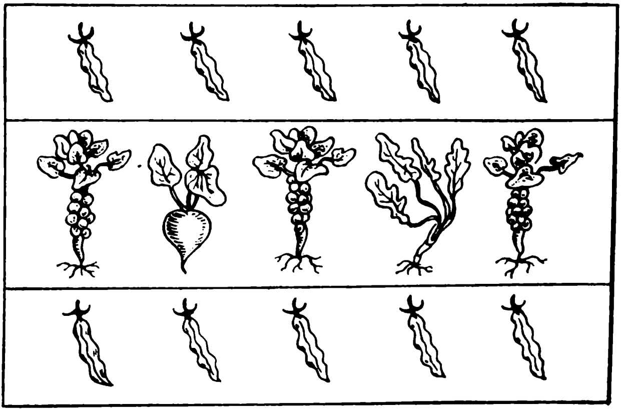

Figure 11
Brussels sprouts planted between the rows of peas. The radish and the cress are sown between cabbages. At first the peas are harvested and then the radish. The cress goes on growing in the shadow of old cabbage plants and it may be used in a cold season

of lettuce and land cress are arranged on the surface and that is why there is no rivalry between them and the main crop.

A similar example is that of the simultaneous sowing of radish and beet, carrot, onion, parsnip or salsify in one row. In this case the harvesting of early-ripening radish serves as the first cutting for a second crop (R.F. Fletcher, 1972).

Taking into consideration the early ripening and compatibility of vegetable crops, Larckom recommends the following combinations of various crops. The first crop (late-ripening) is the main crop and the second (fast-ripening) is the packer. If they are not simultaneously sown then the crop that comes first must be sown or planted first. Combinations of vegetable crops are as follows: peas and carrot, carrot and radish, parsnip and radish, cabbage and radish, cabbage and green onion, corn and spinach, corn and lettuce, tomato and spinach, tomato and radish, tomato and lettuce, Swiss chard and pepper, onion and radish.

Along with the fast ripening property, the main factors to be taken into consideration when composing mixtures are the growth and development rates of combined crops, especially in the initial stages. As is well known, the seeds of different vegetable plants do not germinate at the same rate. If radish seeds sprout in 4 days, parsnip and parsley seeds require 15 days.

Germination Time (in Days) of Various Vegetable Crops (from W.E. Shewell, 1973)

Radish	4-7
Swiss chard, broccoli, Brussels sprouts, cabbage, cauliflower, kale, kohlrabi, leek, lettuce, rutabaga, turnip	5-10
Chicory, cucumber, endive, onion, spinach, tomato	6-12
Peas, rhubarb, salsify, spinach	7-16
Beet, carrot, celery	10-20
Parsley, parsnip	15-20
Asparagus	25

The quick germination of some vegetable crops is widely used in vegetable growing when the crops are planted as beacon plants. For example, small radish and radish seeds are sown together with onion or carrot seeds, only the first group of seeds are sown less densely than usual. The early radish or small radish shoots help to easily locate the rows of the main crop, whose seeds grow slower. This facilitates taking care of the plants. In addition, small radish and radish are fast-ripening crops and they do not hinder the further growth and development of the main crop.

Some vegetables grow very rapidly in their initial stages, while others grow intensely in the second half of their vegetation period. This must also be taken into account when composing mixed sowings of vegetable crops. A good example is a combination of root crops (carrot, beet, chicory, etc.) with bulb onion and cucumber. After germination the onions grow and develop quickly, but the root crops grow very slowly. The maximum growth of the latter crops occurs when the onions shed their leaves.

5

The Land Plot; Its Location, Size, and Cultivation

In tropical countries the rural population has home gardens alongside their main fields. Commercial crops are grown on the main fields. In recent years, a great number of urban dwellers have a small plot of land in front of their homes, which can satisfy most of the family requirements for vegetables. Under tropical conditions, with the proper organization and effective use of the land, a family consisting of five members can be sufficiently supplied with vegetables from a small plot of land with an area of 200 sq m.

The selection of a plot for vegetable crops in a home garden is, as a rule, limited. It is better to have a plot on the sunny southern or eastern side of the house. Loose loams rich in organic matter make the most suitable soils for growing vegetables. When choosing a plot, attention must be paid to the following:

1. A flat or slightly inclined plot is convenient for vegetable cultivation.
2. The plot must be close to the sources of irrigation.
3. The roots of nearby trees must not grow and spread in the arable layer, and the trees must not shade the plot during the twenty-four hours of the day.

The length of the plot should be 2-3 times longer than its width. The soil should be kept in good condition. Perennial and tall vegetable plants should be planted in the northern part of the plot. All the fast-ripening vegetables should be grouped in one place in order to more effectively use this area by doing repetitive, intermediate, and mixed sowings. Root crops should be grown in beds. Proper succession of cropping must be conducted on the plot. It is better to alternate crops of different families. All the spicy crops that are used in small amounts should be grown near the house or between the rows of other crops. Such vegetables as bean, tomato, and brinjal ripen well when grown indoors in various containers.

L.S.S. Kumar (1963) offers a layout of vegetable crops for home gardens in India, which presumes the separation of a plot into four parts, where the following vegetable crops are grown depending on the season:

Plot 1. In summer—root crops and suran (Amorphophallus Campanulatus), ginger (Zingiber officinallis); in hot weather—brinjal, cluster bean, eggplant, and tomato.

Plot 2. In summer—various kinds of leafy vegetables; in winter—brinjal and cabbages.

Plot 3. In summer—tomato, sweet pepper, leafy vegetables; in winter—onion and garlic.

Plot 4. In summer—common bean, cluster bean and eggplant, in winter—leafy vegetables and Brussels sprouts.

The composition of the crops may be changed depending on the region and demand for vegetables. In each case a vegetable gardener must know what he is to grow and where to locate the crops. The plot layouts and the

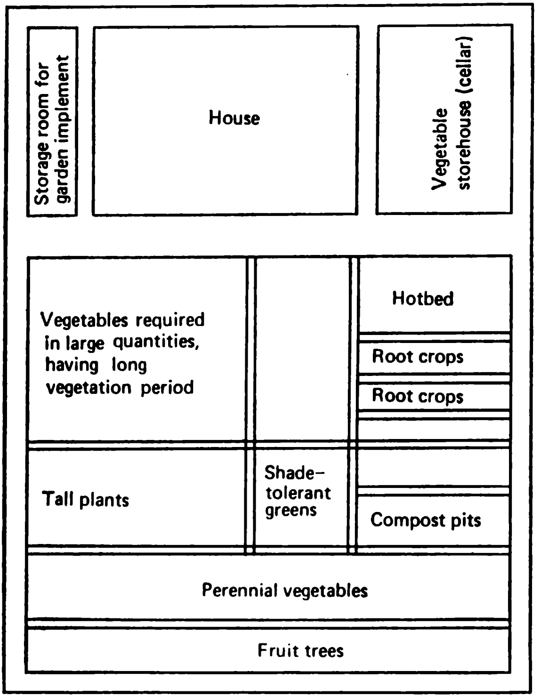
Storage room for garden implement
House
Vegetable storehouse (cellar)
Vegetables required in large quantities, having long vegetation period
Hotbed
Root crops
Root crops
Tall plants
Shade-tolerant greens
Compost pits
Perennial vegetables
Fruit trees

Figure 12
Convenient plan of a home garden and arrangement of farm crops on it

distribution of crops on it with regard for work convenience, peculiarities of field management and requirements for lighting of the grown crops are shown in Figs. 12 and 13. The plot should be located on the southeastern side of the house, if possible. A seedbed should be lo-

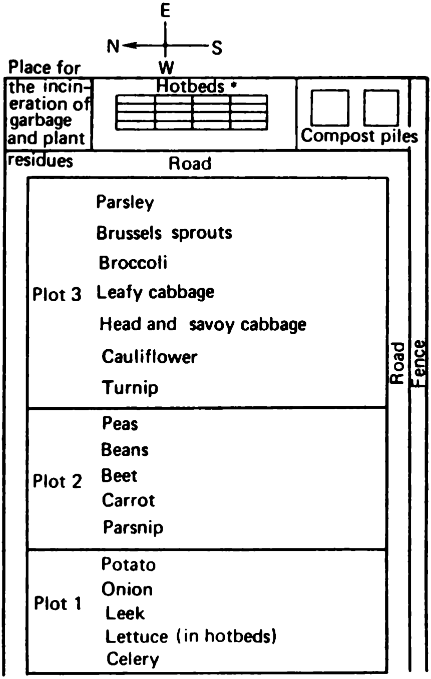

Figure 13
Arrangement of cultures grown in a home garden

cated closer to the house, because the preparation of a seedbed and the growing of seedlings takes much time and after its selection the place is, as a rule, used for growing the most labour-intensive crops. Compost pits (there are usually three) should be dug as far as possible from the house and in the shade. Compost is moved from one pit to another every month. This remixes it and leaves room for new wastes. After the compost has been in the third pit for about a month, i.e., three months after it was added to the first compost pit, it may be added to the plot. The first pit is filled with all kinds of kitchen wastes, residues of plants after harvesting, weeds, and fallen leaves. After that the obtained mass is moistened with water; peat and other nutrients are added to it.

Location of Crops

The crops should be located on the plot so as not to shade each other or compete for water and nutrients. The tall vegetable crops should be located on the periphery of the plot and as close to the south as possible. This also concerns fruit trees. Perennial vegetables should be located separately in one corner of the vegetable garden plot, so that other vegetable plants can be cared for without hindrance. All labour-intensive crops must be planted closer to the house in order to avoid frequent walking over the plot. Crops that do not require special conditions but that are harvested often and in small quantities (spicy vegetables) are also best located near the house. Some aromatic and flower-bearing plants repel insects. They may be scattered over the plot or over its periphery. Sometimes, it is advantageous to grow these crops near the hotbed, closer to the most vulnerable crops. In tropical zones, to protect animals from the encroachment of animals, a pit is dug around the plot and thorny shrubs or sharpened bamboo or wooden pegs are located along its sides.

Further successful harvests depend on the correct application of various measures for the cultivation of vegetable crops. The main points are: preparation of a plot and a hotbed; preparation of sowing or planting material; providing soil with fertilizers; determination of optimum times for sowing or planting; choosing the most effective method of sowing and determining the appropriate density of plants; addition of extra fertilizers; weed, pest, and disease control; timely harvesting.

Soil Cultivation

If the ground was not previously cultivated, it must first be cleared. Ground pioneering consists in chopping away large trees and bushes, digging out big knotty roots and incinerating them. During incineration, the seeds of many weed plants are destroyed, many pests die, and the availability of nutrients is increased. With correct further cultivation, incineration improves soil structure, making it looser. It should be noted that incineration somewhat decreases soil acidity. Sometimes, a few large trees are left for shading shade-requiring crops and seedlings. In grass savannahs pioneering consists mainly in incinerating and burying the grass. After that the soil is hoed to a small depth; stones and other foreign objects are removed from the plot.

Soil cultivation pursues many objects. The main ones are: loosening of soil, improvement of water and air regimes, elimination of weeds, worsening the conditions for the reproduction of pests and pathogens, incorporation of fertilizers, improvement of the soil nutritive regime, control of water and wind erosion. Sometimes, green manure is incorporated through cultivation, while deep cultivation is used to improve podzolic and solonets soils.

In tropical areas fields are ploughed to a small depth (often 10-15 cm). This is conditioned by many difficulties, connected with soil compactness, the presence of many roots in the soil, and the dryness of the soil. Soil cultivation is conducted after rain has fallen, when the soil is softer. It would be better, however, to cultivate the soil prior to the rainy season, so that the loose soil could be saturated and would accumulate more moisture. If the soil is cultivated after a particular crop is harvested, the time for cultivation is determined by the completion of the harvesting of the previous crop. The time of cultivation also depends on the time the previous crop was sown and on the type of organic fertilizers used. If manure is used, it must be incorporated beforehand, so that it can decay prior to sowing. If green manure is ploughed, it must be cultivated earlier because manure decays completely only after one or two months. It proceeds more quickly and intensively under warm humid conditions.

One more factor that determines the time of cultivation is the soil humidity. The number of cultivations depends on how weedy the field is, on the preceding crop, and on the soil structure. Two cultivations are conducted when there are abundant weeds. The fields are cultivated again 10-15 days later when the remaining weed seeds grow. If the previous crop was a wide-rowed one, after which the soil becomes loose (owing to frequent row cultivations) and the number of weeds decreases, one may restrict oneself to one cultivation. The field should be cultivated a second time if large lumps of soil remain after the first cultivation (small-seed crops require soil of a thinner structure than large-seed crops do for uniform coverage with soil). Large-seed crops also grow well in coarsely tilled ground. We must take into consideration the fact that soil that is too loose is easily subjected to erosion.

All that has been mentioned above concerns mainly large-scale farming. In home gardens the task is facilitated by the fact that because of the small sizes of the plots the soil can always be kept in good condition. In both cases the depth of cultivation is controlled by the crop's requirement. Root crops, tuber-bearing plants and some other deep-rooted crops require a deeper loose soil layer than the majority of leafy vegetables. Perennial crops, such as asparagus, require the deepest cultivation.

6

Succession Croppings and Intermediate Sowings

Scientifically-based crop alternation is necessary for maintaining soil fertility, complete and economical consumption of nutrients and water, rational use of time, prevention of diseases and pests and control of weeds. The alternation of crops in tropical areas during irrigation is particularly effective. In home garden plots the alternation of crops in space, like succession cropping, is very rare. This is related to the small size of fields and the gardener's wish to grow certain economically justifiable crops. In addition, in tropical and, to some extent, subtropical, areas, two or three crops are grown on one plot in a year, which decreases the necessity of crop alternation in space. However, on large fields, it is advisable to apply succession croppings. The field is divided into several plots. There may be three or more plots, depending on the size of the field and the set of grown crops. For example, when the field is divided into three small plots, vegetable crops may be grown as indicated in Fig. 14.

The group of crops grown on each plot is conditional and plants from other groups can be planted for intermediate and combined growing.

The repeated cultivation of any crop on one and the same plot must be avoided. With more intensive succession croppings the crops of one family are not even grown on the same plot.

1st year

Plot 1	Plot 2	Plot 3
Root crops and tubers	Cabbage leafy vegetables	Fruit-bearing vegetables

2nd year

Fruit-bearing vegetables	Root crops and tubers	Cabbage and leafy vegetables

3rd year

Cabbage and leafy vegetables	Fruit-bearing. vegetables	Root crops and tubers

Figure 14
The alternation of crops in a home garden

Succession croppings, i.e. the alternation of crops after a specific period of time and on a specific territory are of special importance in tropical and subtropical areas. The diagram for succession croppings (Fig. 15) suggested by Choudhury (1975), an Indian scientist, is a good example of such alternation of crops in time and space.

The diagram shows the calendar times for growing vegetable crops on different plots over a year. In the following years the diagrams must be changed for each plot. Such alternation allows for the effective use of space and time and it is possible to achieve high yields of the main vegetable crops throughout the year. The alternation of vegetable crops with rice and sunflower and with other crops is also practised. Here vegetables are grown as intermediate crops. The economic effect in

<table>
<tr><th rowspan="2">Plot No.</th><th colspan="24">Months</th></tr>
<tr><th colspan="2">I</th><th colspan="2">II</th><th colspan="2">III</th><th colspan="2">IV</th><th colspan="2">V</th><th colspan="2">VI</th><th colspan="2">VII</th><th colspan="2">VIII</th><th colspan="2">IX</th><th colspan="2">X</th><th colspan="2">XI</th><th colspan="2">XII</th></tr>
<tr><td>1</td><td colspan="12">Onion</td><td colspan="7">Cauliflower</td><td colspan="5">Lettuce</td></tr>
<tr><td>2</td><td colspan="2">Lettuce</td><td colspan="8">Eggplant</td><td colspan="8">Sweet potato</td><td colspan="6">Potato, Cowpea</td></tr>
<tr><td>3</td><td colspan="2">Potato-Cowpea</td><td colspan="10">Watermelon</td><td colspan="9">Brinjal</td><td colspan="3">Green onion</td></tr>
<tr><td>4</td><td colspan="2">Green onion</td><td colspan="9">Brinjal</td><td colspan="5">Radish, Swiss chard</td><td colspan="2"></td><td colspan="6">Cabbage</td></tr>
<tr><td>5</td><td colspan="11">Tomato</td><td colspan="6">Cowpea</td><td colspan="7">Cauliflower</td></tr>
<tr><td>6</td><td colspan="3">Kohl-rabi</td><td colspan="14">Two harvests of cluster bean</td><td colspan="6">Beans</td><td colspan="1">Radish</td></tr>
<tr><td>7</td><td colspan="10">Radish</td><td colspan="7">Eggplant, carrot</td><td colspan="4">Cauli-flower</td><td colspan="3">Cauli-flower (second harvest)</td></tr>
<tr><td>8</td><td colspan="3">Cauli-flower (second harvest)</td><td colspan="9">Watermelon</td><td colspan="4">Fallow</td><td colspan="4">Turnip, cabbage</td><td colspan="4">Cauli-flower</td></tr>
</table>

Figure 15
Alternation of vegetable crops during a year for a vegetable garden of 200 sq m in area divided into eight sectors in Northern India (from B. Choudhury, 1975)

this case depends on the set of crops. The efficiency of different kinds of succession croppings when growing vegetable crops and rice is given in Table 18.

In the given example, the crops were selected with regard for the demand of the local population of Karnataka State. The low yielding capacity of many crops is, obviously, the consequence of soil deficiency in nitrogen and phosphorus. Some crops (peas and brinjal) are not cost-effective. The first two alternation schemes that include tomato are the most effective and the schemes that include tomato, rice, and cabbage are the most profitable. Investigation of this type should be conducted in each zone, using a large set of vegetables and on fertile soil.

In African countries the main crops used in succession croppings are either food crops, e.g. yams and colocasia (cocoyam), or crops that are for sale, such as rice. Rice is grown mostly as a one-crop system (I.F. Nweke, 1981). Depending on the type of soil and its physicomechanical properties, the following types of succession croppings, in which yams are the main crop, are used:

I. 1st year—yams in a mixture with other vegetable crops; 2nd and 3rd years—colocasia with vegetable crops.

II. 1st year—yams in mixed sowings; 2nd—manioc; 3rd—fallow; 4th—yams in mixed sowings; 5th—manioc.

III. 1st year—yams with vegetable crops; 2nd year—manioc; 3rd and 4th years—fallow, then the sequence is repeated.

Table 18

The Economic Efficiency of Growing Various Crops in Rotation in Southern India (from I.V. Rao et at., 1978)

Rotation diagram	Yielding capacity		Cost of cultivation, rupees*/ha	Cost of product	Period of growth, days
	ton/ha	kg/ha/day			
Tomato	33.2	237	2198	9 969	140
Sunflower	1.7	17	1707	2 004	101
Cabbage	11.3	106	2018	6 792	107
Rotation total			8182	18 765	348
Tomato	33.8	248	2198	10 146	140
Rice	7.7	73	2562	7 730	106
Peas	0.83	11	1444	830	73
Rotation total			8491	18 706	319
Brinjal	18.7	134	2128	7 484	140
Cowpea	3.3	44	1180	1 675	77
Bean	2.9	27	1476	2 058	108
Rotation total			6929	11 217	325
Eggplant	6.0	66	1848	3 010	91
Rice	6.8	64	2517	6 830	106
Brinjal	5.1	40	2057	2 028	128
Rotation total			8731	11 868	325

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* 1 rouble = 13 rupees

IV. 1st year—manioc with other crops; 2nd year—manioc; 3rd and 4th years—fallow, then the sequence is repeated.

Yams, colocasia and manioc are grown together with corn or other optional.

The organization of succession croppings, including industrial, cereal, commercial, and green manure crops of different kinds, is very important for the commodity production of vegetables on large plots. Here the repetition of

Table 19

The Relation of Different Crops and Families to

Subsequent crops and forerunners	Solanaceae	Cucurbitaceae	Fabaceae
Solanaceae	– – –	– – –	0
Cucurbitaceae	– – –	– – –	0
Fabaceae	0	0	– – –
Apiaceae	0	0	0
Asteraceae	0	0	0
Chenopodiaceae (spinaches)	0	0	0
Tuber-bearing plants	0	0	0
Eggplant	0	0	0
Onion	+++	+++	+++
Tobacco	0	0	0
Cereals	+++	+++	+++
Sugercane	+++	+++	+++
Perennial grasses	+++	+++	+++
Green manure from cereals	+++	+++	+++
Green manure from legumes	– – –	– – –	– – –
Manure	+++	+++	0

– – –, nonprofitable; 0, satisfactory; +++, profitable.

crops that have common diseases and pests must be avoided. The relation of individual crops to their predecessors must also be taken into account. As is shown in Table 19, vegetable crops of different families grow well after the majority of crops. And such crops as onion, with its superficial root system and a low removal of nutrients from the soil, are good forerunners for almost all the vegetables. But the onion itself does not easily tolerate

Their Forerunners (from C.-M. Messianen, 1974)

Apiaceae	Asteraceae	Chenopodiaceae (spinaches)	Tuber-bearing plants	Egg-plant	Onion
0	0	0	0	0	+++
0	0	0	0	0	+++
0	0	0	0	0	+++
---	0	0	0	0	+++
0	---	0	0	0	+++
0	0	---	0	0	+++
0	0	0	---	0	+++
0	0	0	0	---	+++
+++	+++	+++	+++	+++	---
0	0	0	0	0	+++
+++	+++	+++	+++	+++	---
+++	+++	+++	+++	+++	---
+++	+++	+++	+++	+++	---
+++	+++	+++	+++	+++	---
0	0	0	+++	+++	---
+++	---	+++	+++	+++	---

compact soil, which results after sowing many crops, and it grows well when it is planted after other vegetables. All vegetable plants, except for onion and legumes, grow well after applying dung and green manures.

In the tropics and subtropics, where fertilizers, including nitrogen, are used in very small quantities, green manures are more promising. In this case they may be located as intermediate or main crops. They promote the accumulation of carbon and nitrogen in poor tropical soils and also the improvement of the soil structure. Research on succession croppings and on discovering the best forerunners and green manures should be conducted taking into consideration the cultivated crops, the specific climatic conditions, and the agrotechnics of the main, as well as the preceding, crop.

It should be borne in mind that in small plots, when plants are alternated, some vegetable plants (for example, peas, carrot, or beet) are able to use nutrients extracted from deep layers of the soil and from almost inaccessible compounds. These plants should be alternated with crops having weak root systems (onion, cucumber, or greens). We should also consider specific nutritional requirements of various crops. For example, cabbage, tomato, greens, and some other crops extract a large amount of nitrogen from the soil, while legumes enrich the soil with nitrogen. A difference is also observed when organic fertilizers are added. Immediately after their addition cucumber, cabbage, pumpkin, marrow, leek, celery, and similar crops should be planted. In the following years, crops that efficiently utilize the manure residues should be planted. It is better to grow root crops, which require few fertilizers, after various kinds of cabbage, leafy vegetables, cucumbers, tomatoes, and other crops, which require a large amount of organic fertilizers. The root crops efficiently utilize the remaining nutrient stores in the soil and also assimilate the large quantity of nutrients that have seeped into deeper horizons as a result of washing away.

Compatibility of Vegetable Crops

When planning different types of succession cropping, the density of planting and the selection of components for mixed sowings it is necessary to consider the biochemical interaction of different kinds of plants due to the presence of different chemical substances. These substances are called allelochemicals, and the science that studies them is called allelochemistry. The main substances that influence various organisms are the following ones:

Antibiotics—substances formed by accompanying microorganisms that suppress other microorganisms.

Marasmines—substances of extinction, secretion products of microorganisms that suppress the vital activity of higher plants.

Phytoncides—substances produced by plants that suppress the growth of microorganisms (sometimes they suppress the growth of antagonist plants, especially seedlings).

Colines—substances excreted by plants and inhibiting the development of other higher plants.

Allomones—substances that "understand" individual members of different species. These substances make possible the functions of plants and insects that are necessary for the plants themselves. They include recovery and pollination attractants, substances that scare off intruders and various poisons.

Cayromones—substances that also participate in "communication" between species, but by suppressing interaction. For example, the leaves of black walnut, plane tree, dwarf oak, and various maples excrete a substance, which, when it falls to the ground with rain, "warns" other plants not to grow near the roots of the tree (R. Louise, 1976).

The mechanisms of interaction and their results are diverse. The science that studies the interactions of plants in their natural biocenoses or in mixed sowings is called allelopathy. This science must be studied when selecting components in mixed sowings. A suppression of spinach, for example, is observed when it is grown together with radish, and radish growth in turn is suppressed by the root excretions of onion.

The compatibility or incompatibility of different vegetable crops reflects their mutual favourable or inhibiting influence. However, in the majority of cases, the nature and mechanisms of these interactions have hardly been studied and, when composing mixed sowings, people are mainly guided by individual observations and the century-old experience of amateur vegetable growers (Fig. 16).

Examples of the positive influence of joint sowings are lettuce, carrot, and radish; radish and chervil, turnip and peas; strawberry and lettuce or spinach; beans with corn or summer savory; horseradish and potato; kohlrabi with cucumber, onion, and beet; and tomato with parsley or sweet basil.

The inhibiting influence is observed when, for example, the following combinations are grown together: beet and mustard, grain legumes and alliaceae, broccoli and tomato, cauliflower and tomato or strawberry, cucumber with potato and spicy crops, kohlrabi with strawberry or tomato, parsnip with onion and garlic, potato with pumpkin, tomato and cucumber, radish and hyssop. It should be mentioned that the inhibiting or favourable influence depends also on the number of plants in a mixture. For example, a moderate amount of bean plants has a favourable influence on leek or celery, while too many bean plants inhibit the latter (R. Louise, 1976).

A number of vegetable crops (sweet basil, borage, lavender, sage, spinach, and tomato) contain saponine, a biologically active substance that promotes the intensive growth and development of accompanying plants (Y. V. Hubmann, 1979). These plants are good components in mixed sowings and interseedings and they are also the best forerunners for other crops· when other compatibility conditions are met. Interestingly, some crops (soya, for example) are “friendly” to all crops and have a favourable influence on the adjacent crop, while others, like fennel, are "hostile" to them and inhibit the growth of all the adjacent crops. Some crops (caraway, amaranth, etc.) have a favourable influence on their neighbours by improving the physical properties of the soil and increasing the availability of nutrients in it.

The excretions of asparagus kill the nematodes that harm tomato plants. In the tropics the cultivation of Egyptian onion with the crops that are injured by pests will protect these crops from damage. Some aromatic plants are especially valuable in this respect; therefore, these plants should be scattered throughout the whole vegetable garden to decrease the damage inflicted by pests.

Another, none-the-less-important, factor is the phytoncidal properties of some plants. At present, more than 300 plant species that produce phytoncides are known. In some cases the phytoncides slow down the growth of the plant-antagonists; in other cases they kill pathogenic microbes. Phytoncides may have different degrees of activity. Onion phytoncides are highly active. They may be used to fight Phytophtora infestants. Onion, garlic, and radish phytoncides are also highly destructive to conidiums and spores of phytophtora, ascohitu fungus, and the stimulus of vascular bacteriosis of cabbage. And such crops as beet, carrot, dill, parsley, cabbage, and lettuce hinder the development of phytophtora. Tomato, cucumber, pumpkin, and melon possess the same property. Horseradish, sown togeth-

or with potato, increases the latter's disease resistance. Mustard reduces the populations of specific kinds of nematodes in the soil.

There are many indirect effects caused by the chemical substances discharged by plants. It has been discovered that the juice of onion and garlic bulbs contains the same inhibitors as the juice of horseradish roots and kohlrabi caulocarpic fruits. The inhibitors are volatile oils, which, while being accumulated in the soil, inhibit the germination of seeds of other crops. The root secretions of onion, head lettuce, and rutabaga decrease the speed of nitrification by acting on the microorganisms that take part in this process (A. Rice, 1978). All these effects are to be taken into account when selecting crops for mixed sowings.

7

Field Management for Growing Vegetable Plants

Fertilizers

Vegetable crops are characterized by increased nutritional requirements. In tropical and subtropical areas it is impossible to obtain high vegetable yields without the use of organic and mineral fertilizers. The most effective under these conditions is the dressing of the soil with organic fertilizers. Such crops as tomato and potato react well to organic fertilizers. In tropical areas three kinds of organic fertilizers are widely used: manure, compost, and green manure. Heavy doses of manure or compost for root crops increase their yielding capacity, yet nevertheless, lead to a large branching and cracking of roots. It should be noted that onion prefers well-decomposed manure, while cucumbers react better to fresh manure. Also crops with long vegetation periods must be grown on fresh or slightly decomposed manure, so that by the time of their rapid development the manure is in a well-decomposed state. Generally, the soil should be covered with organic fertilizers (manure, compost) during its main tillage 15-20 days before seeding or planting of crops. In subtropical areas this may be done slightly earlier.

Experiments conducted in Kenya demonstrated that the use of manure, even in a small quantity (7.38 tons per hectare), was highly effective. This led to a 1.5 times increase in the yield of corn and manioc, and the yield of the sweet potato increased by more than two times (I. I. Sinyagin, 1968). In tropical areas the dressing of 10-20 tons of manure per hectare yields good results. Green manure management is a very effective and cheap method of soil enrichment with organic fertilizers. Leguminous plants, used as green manure crops, may be grown between the rows of the basic crop and, after its harvesting, they are incorporated into the soil; or they may be grown in the time interval between the harvesting time of the previous crop and the sowing time of the successor crop. This can be done in tropical areas because the green manure crop grows quickly, and when it is incorporated into the soil with a lot of moisture, it quickly decomposes.

The use of organic fertilizers does not exclude the subsequent addition of mineral fertilizers, which are better assimilated by plants in comparison with organic ones. The use of phosphorus fertilizers is especially important in tropical areas, because in tropical soils, plants often lack phosphorus. Both organic and mineral fertilizers are incorporated into the soil during the main soil tillage and are well mixed with it. The types of fertilizers and the amount to be used depend on the crop, the soil fertility, and the availability of the fertilizers. B. Choudhury (1968) considers it obligatory to add 10-12 kg of manure or compost and 150 g of ammonium sulphate and superphosphate before sowing. Table 20 lists the

Table 20

Recommended Doses of Mineral Fertilizers (Converted for Standard Manure) for Vegetable Crops Grown in Soil of Average Productivity (from B. Choudhury, 1979)

Crop	Manure, ton/ha	Ammonium sulphate, kg/ha	Simple superphosphate, kg/ha	Potassium sulphate or potash manure, kg/ha
Potato	30	400+200**	500	140
Tomato	20-25	275+275	550	175
Brinjal	20-25	250+250	250	120
Pepper	30-50	175+175	175	100
Cauliflower	15-20	300+200	400	100*
Cabbage	20-25	325+325	270	75*
Bean	25-50	250	500	125
Eggplant	30	300+300	350	125*
Beet	—	350	500	150*
Onion	20	600	300	220*
Peas	20	125	350	120*
Watermelon	30-35	200+200	250	120*
Lettuce	—	500	300	150*

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* Dressed during the preparation of soil before sowing.
** Dressed in a month after sowing or planting.

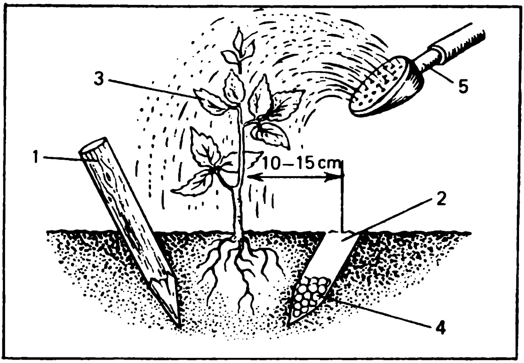

Figure 16
A method of local dressing of plants with mineral fertilizers: a wooden peg (1) with which holes are dug near plants (2) at a distance of 10-15 cm from the plant (3) into which granules of mineral fertilizers are dressed (4). After this the plant should be watered (5)

doses of various fertilizers for the main vegetable crops for Indian soils. Recently compound fertilizers with various ratios of the main nutrients have become widespread in home vegetable gardens. These are best added as main fertilizers directly before sowing.

The majority of vegetable crops produce good yields with nitrogen fertilization. Half of the nitrogen dose is added as the main one and the other half is added as supplementary. The supplementary fertilizer is added four or six weeks after sowing or planting. When powdered or pelleted nitrogen fertilizers are used in home gardens, it is best to follow the method outlined in Fig. 16. This method of fertilization helps the plants to better assimilate the fertilizer. After adding fertilizers, the plot must be slightly moistened. When the dressing is conducted later, the plants are often sprayed by a solution of carbamide or triple superphosphate. Leaf feeding of phosphorus yields good results with fruit and vegetable crops. These dressings are more often used when growing a crop with a long vegetation period. With leaf feeding of carbamide a solution concentration limit for particular types of plants should be observed.

Permissible Carbamide Concentration (%) for Dressing of Vegetable Crops (from Anspok et al. 1981)

Beans, cucumber	0.3-0.4	Onion	1.6-2.0
Tomato, corn	0.4-0.6	Beet	1.5-2.0
Cabbage, potato	0.8-1.6	Carrot	1.2-3.0

Some vegetable crops react very well to the dressing of microfertilizers, especially in tropical areas, where a deficiency of micronutrients is often encountered because of hard washing away and leaching. In the tropical soils of Africa there is a lack of sulphur, boron, copper, zinc, and also iodine and bromine. The dressing of sulphur (25 kg/ha) increased the yields of some crops five time (I.A. Denisov, 1971). Most often the plants suffer from a deficiency of micronutrients, when they are grown on peaty and other soils with high acidity or alkalinity. O'Toole Lorcan (1972) provides information on the possible deficiency of micronutrients depending on the pH value of the soil,

Possible Deficiency of Micronutrients in Soils With Different pH Values (O'Toole Lorcan, 1972)

$pH < 4.8$	$pH = 5.0\text{-}6.0$	$pH > 6.2$
Danger of molybdenum and magnesium deficiency	Optimum content of all micronutrients	Deficiency of zinc, manganese, iron and copper

In Table 21 information on the reaction of different vegetables to the addition of micronutrients when they are grown in peaty soils is given. Only when all these rules are observed, it is possible to get high good-quality yields of vegetables. Insufficient and non-scientifically based application of fertilizers is the main reason for low yields in developing countries.

Sowing and Planting

Two methods, as follows, are used when growing vegetable plants: the sowing of seeds straight on the plot (non-transplanting crop) and the sowing of seeds, first in small hotbeds, with the further planting of the young plants (seedling) in the field (seedling crop).

In tropical and subtropical areas the majority of vegetable crops (broccoli, Brussels sprouts, Chinese cabbage, cabbage, cauliflower, celery, brinjal, tomato, garlic, onion, lettuce, pepper, etc.) are cultivated by the seedling method. Some crops, for example, carrot, peas, bean, cucumber, small radish, radish, watermelon, melon, pumpkin, spinach, eggplant, corn, and others are grown only by sowing seeds directly in the ground. However, in the majority of cases, the choice of a method

Table 21

Reaction of Vegetables to Some Micronutrients When Grown in Peaty Soil (from O'Toole Lorcan, 1972)

Crop	Manganese	Boron	Copper	Other important micronutrients
Asparagus	Low	Low	Low	—
Bean	Ditto	None	Ditto	Zinc
Broccoli	Average	Average	Average	Molybdenum
Cabbage	Ditto	Ditto	Ditto	—
Carrot	Ditto	Ditto	Ditto	—
Cauliflower	Ditto	High	Ditto	Molybdenum
Celery	Ditto	Ditto	Ditto	—
Lettuce	High	Average	High	Molybdenum
Onion	Ditto	None	Ditto	Zinc and molybdenum
Parsnip	Low	Average	Average	—
Peas	High	None	Low	Molybdenum
Potato	Ditto	Ditto	Ditto	—
Radish	Ditto	Average	Average	—
Spinach	Ditto	Ditto	High	Molybdenum
Beet	Average	High	Ditto	—
Turnip	Ditto	Ditto	Average	—

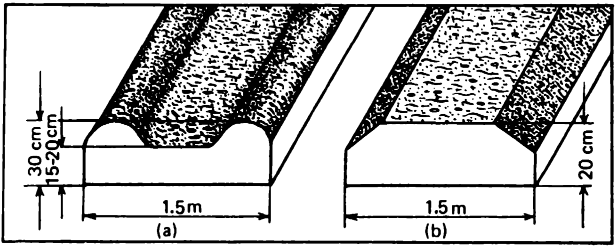

Figure 17
Types of beds used for growing seedlings of vegetable crops:
(*a*) dry season bed (good water retention), (*b*) rainy season (water may drain freely)

depends on the duration of the vegetation period, the peculiarities of the climate, the availability of labour, and the specific biological characteristics of the crop.

Preparation of a hotbed. As a rule, the most fertile plot is selected as a hotbed, which is thoroughly cultivated and then disinfected with a formalin solution or by steaming. The upper layer of the soil must be absolutely free of the seeds of weeds, pests, and pathogens. After that the soil is dressed with fertilizers and thoroughly loosened. The seedlings are, as a rule, grown in planting beds that are between 1.2 and 1.5 m wide; the length is optional and the height is 15-30 cm. Depending on the growing season and precipitation, the beds are made of different shape (Fig. 17). The first method requires making ridges on the edges of the bed, which are used for growing seedlings in a dry season or in arid regions; the second method is when the bed surface is made so that it can drain on both sides, and it is mainly used in humid areas during the rainy season to avoid overwatering and seedlings' disease. The seedlings for a small plot can be grown in boxes or other containers on well-disinfected soil. The thickness of the soil layer depends on the depth of the root system and the length of time during which the plants are grown in boxes. For some crops (tomato, brinjal, etc.) the seedlings may be grown in small pots made of various materials.

Sowing of seeds in front hotbeds and growing of seedlings. The seeds of the majority of vegetable crops are sown at a depth of 2-5 cm. They are sown in the previously made channels or ridges on beds. Prior to sowing, the seeds are treated with chemicals that protect against pests and diseases. Soaking of seeds in solutions containing micronutrients yields good results. The distance between the rows and the number of seeds in one row depend on the crop. When small seeds are sown, they are first thoroughly mixed in a separate container with dry disinfected soil and then the mixture is sown into the channels. After sowing, the seeds are covered with soil and slightly compacted by hand. If the soil is dry, its upper two-centimetre-thick layer is slightly moistened, taking care not to destroy it. Afterwards, when the shoots appear they are watered more rarely, but more abundantly. Sometimes in tropical areas different shading devices are used to avoid overheating of the seedlings by the burning rays of the sun. The seedlings are cared for by watering, loosening them in their beds, spraying against diseases and pests and removing sick plants and weeds. Sometimes, fartilizers are added to the seedlings. The seedlings of some crops are thinned so that they do not grow too densely. In this case the weak plants are removed.

Selection and planting of seedlings. The period of time spent in hotbeds depends on the crop, the degree of development of the seedlings, weather conditions, and other factors. The seedlings of the majority of vegetable crops are planted in the field at the age of 4-6 weeks. By the time of selection they should have a well-developed root system and they should look healthy. Before the seedlings are planted, the hotbed is flooded with water to facilitate their selection. The seedlings are dug out with clumps of earth and held by the stem base. The roots and the above-ground part of the seedlings must not be damaged. It is better to select and plant seedlings on cloudy days and at night when it is not hot. The selected seedlings are planted on a well-prepared field in channels or on ridges. The seedlings must be planted slightly deeper than they were in the hotbed. The soil around the root system is compacted and covered with loose earth. The seedlings are watered immediately after planting. Sometimes, during planting the plants are watered with a fertilizer solution that is rich in phosphorus. The fertilizer is dissolved in water and the soil around the root system is moistened and then covered with loose dry soil. With this treatment the plants will endure transplanting better and will quickly start to grow.

Methods of planting. The method of planting depends on the crop and the region where it is grown. Planting may be channel, ridge, and channel-ridge. In some regions, especially, in tropical Africa, tuber crops are planted in previously prepared heaps.

Channel planting is used for growing crops with a high moisture requirement and with root systems that are located near the surface (for example, various kinds of onion). This method is also used in arid regions to simplify irrigation. The choice between ridge-planting or planting in beds is of great significance when growing crops with high moisture requirements in excessively humid areas. The cultivation of ginger (Zingiber officinale Roscos) in the humid tropical areas of India presents a good example: two rows of ginger are planted in the bed, while the ditches drain the water away (L.S.S. Kumar, 1963).

Channel-ridge planting is often used when growing wide-row crops in mixed sowings. The plants may be planted on the bottom of the channel and on its sides. Harvesting is greatly facilitated by planting tuber-bearing crops in heaps. In addition, this method allows for the better utilization of the upper loose layer of heavy soils. Also, the making of heaps in areas with abundant rainfall during the rainy season protects the roots from excessive moisture.

The height of the heap depends on the crop, but sometimes reaches 1 metre. Crops are planted on the tops of the heaps. Many crops (for example, peanut and corn) are grown on heaps. Beds of various configurations are widely used when growing vegetable crops of entire seeding or crops with small land area (nutrition) requirements. Beds with ridges on the sides are used when growing crops with high moisture requirements or crops requiring some flooding. Various types of greens, as pure and mixed sowing, are mainly grown in beds.

The methods mentioned above are used when sowing seeds. It should be noted that sowing must be done in more loose, levelled ground than that required for planting seedlings. Scattered sowing is used when growing some types of small-seed greens and spices. The sowing in rows method is mainly used for large-seed crops, which require rather large land areas (for example, peas, some kinds of beans, etc.). The sowing of several seeds in clusters located in a row prevails when growing small-seed crops which require large land areas during their development. This method includes the thinning of plants down to one plant per cluster after the shoots appear or a little later. As a rule, weak plants that sprouted poorly are removed. Sometimes a mixture of small-seed crops is sown. In this case the plants are thinned so as to leave the optimum quantity of plants per unit area, taking into consideration their relationship to each other.

Sometimes, in the tropics, in arid regions, when growing vegetables with the use of irrigation, sowing or planting is done in the so-called basins or small checks with an area of between 5 and 10 sq m. Such crops as melons, watermelons, and various types of pumpkins are often grown on these plots.

In the mountains and on highly inclined plots, vegetables are cultivated on artificially made terraces or contoured ridges. Vegetables are planted on the side of the terrace closest to the slope (on terraces with steeply inclined plots) or on the ridges (on shallowly inclined slopes), which prevents soil erosion and creates the best conditions for the water supply of plants.

Areas for Plant Nutrition

The nutrition area, allotted for each plant, depends on the crop, the cultivation method, the soil fertility, and many other factors. For vegetable crops it ranges from 0.03 to 3-4 sq m and depends on the sowing or planting design. The recommended specifications for the major vegetable crops in various zones (Eastern Ethyopia and Southern India) are given in Table 22. Some crops (artichoke, asparagus, various gourds and tuber-bearing vegetable crops) require large nutrition areas because of their growth pattern, while others, such as onions, leafy and root-crop vegetables, which are characterized by a small mass of the aboveground and underground parts of the plant, can be densely sown. The area of nutrition is also determined by the soil fertility and water supply. The more fertile the soil and the better it is supplied with water, the greater the number of plants that can be located per unit

Table 22

Recommended Sowing or Planting Designs for Different Vegetable Crops

Crop	Recommended sowing or planting design, cm	
	For Eastern Ethyopia[1]	For Southern India[2]
Colocasia	—	45×30
Sweet potato	100-120*×30-50**	30×30
Potato	100-120×20-40	23×45
Beet	50-70×5-10	30×30
Carrot	50-70×3-8	30×15
Radish	30-50×1-3	15×30
Celery	70-100×15-50	—
Garlic	50-70×20-30	—
Turnip	40-70×8-10	15×30
Watermelon	200-250×100-150	150×150
Melon	—	150×150
Pumpkin	100-180×100-150	180×180
Cucumber	100-200×60-80	180×180
Brinjal	70-100×50-60	60×30
Eggplant	—	30×30
Pepper	50-80×30-50	30×60
Tomato	100-125×100-125	30×60
Onion	40-80×5-10	15×20
Spinach	30-50×10-15	15×15
Lettuce	50-70×16-30	30×30
Cauliflower	70-100×40-60	—
Cabbage	70-100×40-60	60×60
Brussels sprouts	70-80×40-60	60×60
Broccoli	70-100×40-60	—
Chinese cabbage	70-100×30-60	—
Shallot	15-30×5-10	—
Artichoke	200-250×150-60	—
Asparagus	70-250×45-60	—

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[1] From Haile Michael, 1969.
[2] From C. Bhujanga Rao, 1968.
* Distance between rows.
** Distance between plants in a row.

area and vice versa. It must be remembered that when crops that require a large nutrition area are densely planted, the yield and the size of the vegetables decrease. Dense planting also makes the plants more susceptible to diseases. The area of nutrition also depends on the variety of the crop and, with some crops, such as tomato, on the way the plant is formed. Large tomato varieties, when grown spread (without forming), require a much larger nutrition area than the dwarf variety or than large ones when grown with one or two stems. When vegetables are intensively cultivated and constantly cared for in small home gardens they may be planted more densely than crops cultivated on large plots.

Irrigation

In the tropics and subtropics, especially in arid and semi-arid regions, irrigation is the limiting factor that determines the selection, growing period, and yielding capacity of vegetable crops. When a reliable irrigation source is available, it is possible to achieve high yields of various vegetables throughout the whole year. Vegetable crops have high moisture requirements and they give high yields only with irrigation that is properly timed and of the necessary quantity.

When cultivating vegetables on large areas, irrigation presents an important organizational and agricultural undertake, which requires large capital investments. In the developed countries many irrigation methods, such as surface irrigation along the ridges, spray irrigation, infiltration irrigation, and drop irrigation are widely employed. However, in the developing countries only one method is used—irrigation on the ridges—which is related to the high cost of energy and low level of mechanization. In this method, water from the irrigation system or from wells is supplied to the fields along the ridges. The distribution of water in the plots is achieved by various systems. Furrow irrigation is widely employed when growing wide-row crops. In home garden vegetable growing, plants are irrigated with a hose, different vessels (watering-pot, pail, etc.) and other devices.

The amount of irrigation depends on the purpose of irrigation, the biological characteristics and the developmental stage of the crop, and the type of soil. Some crops require frequent irrigation in small amounts throughout the whole vegetation period. These are crops with a surface root system (onion, radish, small radish, carrot, leafy vegetables, scented plants, and potato). When there is no rain, they must be watered twice a week or more. Crops such as tomato, brinjal, and others must be watered less frequently but more abundantly. Plants of the gourd family (cucurbitaceae) have the highest water requirements, as a rule, only in their early stages of development. All vegetable crops react well to irrigation. The water requirement for the majority of vegetable crops increases as they grow and develop and reaches a maximum when the plant blossoms and fruit forms.

Abundant irrigation with periodic droughts during ripening lead to cracked heads, fruits and tubers. The classification of vegetable crops according to their water requirement and the stage of their maximum water requirement is given in Table 23. Insufficient, as well as excessive, watering of the soil during the flowering and fruit-bearing stages of all crops leads to the falling off of flowers and ovaries and poor ripening of fruits. Abundant irrigation during ripening causes an increase in the water content and a decrease in the quality of vegetables.

In home gardens the rate and periods of irrigation are established and followed based on observation. Two or three irrigations per week when there is no rain yield good results in the majority of vegetables. After every irrigation, when the upper layer of the soil becomes dry, the soil should be loosened in the spaces between the rows. This promotes moisture conservation in the soil and improves aeration. At the same time loosening functions as weeding.

Harvesting

Vegetables are perishable products. Their quality depends to a great extent on how ripe they are and on the storage and shipping conditions. Timely and correct harvesting is the most important factor determining a good harvest, especially for commodity production. Not only the period of harvesting, but also the sorting, packing, and transportation are important.

Table 23

Water Requirement for Different Vegetable Crops

Crop	Water requirement*	Stage of growth with the largest water requirement**
Bean	Small	Pollination, growth, and development of beans
Beet	Very high	During the whole vegetation period
Broccoli	Ditto	In early stages of development to avoid multiple head formation
Cauliflower	Ditto	During head formation
Cabbage	Ditto	During head formation
Carrot	Small	During the whole vegetation period
Swiss chard and other greens	Very high	Ditto
Cucumber	High	Flowering and fruit ripening
Brinjal	Ditto	Flowering and after each collection
Scented plants	Small	Vegetative, when leaves are withering

Table 23 (*concluded*)

Crop	Water requirement*	Stage of growth with the largest water requirement**
Leaf lettuce	Very high	During the whole vegetation period
Head lettuce	Very high	Head forming
Melon	Drought-resistant	Flowering and fruit-ripening
Onion	High	Bulb forming (stop after leaves form)
Peas	Small	Flowering and during fruit development
Pepper	High	Flowering and after each collection
Radish	Very high	During the whole vegetation period
Pumpkin	Drought-resistant	Formation of buds, flowering
Tomato	High	Flowering and after collection
Turnip	Very high	Growth and development of roots

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* From V.M. Markov, 1974.
** From L.J. Coldstein, 1981.

The periods of harvesting depend on the crop and the market demand. The early harvesting of some crops (root crops, tuber-bearing crops, etc.), results in a decrease in their yielding capacity, and late harvesting results in a decrease in quality. Root crops become rough and sometimes crack. When harvested early, potatos and root crops do not store well, but the prices for early potatos are high. Root crops and tuber-bearing crops must not be left in the sun after harvesting, because this may cause burns. They must be harvested when the above-ground mass is maximally developed and the tubers have reached their optimum size. When harvesting, care must be taken not to damage the tubers.

Leafy vegetables are harvested when the leaves reach their optimum sizes, but their juiciness and tenderness are preserved. Immediately after harvesting they must be thoroughly washed and sprinkled with water during packing. This is very important when harvesting during the hot summer season, because harvested produce quickly wilts and its quality worsens. Many vegetables (tomato, cucumber, brinjal, and some leafy vegetables) are harvested repeatedly. This must be done gradually during ripening, and when delayed before use or sale, the vegetables must be stored correctly or undergo processing (canning).

8

The Cultivation Calendar for Vegetable Crops in Tropical and Subtropical Areas

The sowing and harvesting times are determined mostly by the climatic features of the cultivation region and the developmental pattern of the type of vegetable. On the plains of tropical areas, the majority of vegetables can be cultivated practically throughout the whole year. Here, with irrigation, it is possible to obtain three or four harvests of various vegetables per year. The crops are chosen depending on the growing season and the developmental pattern. Immediately after the first crop is harvested the second crop is sown or planted. However, it should be kept in mind that for each crop the growing season and the sowing time are selected so as to provide for a maximum yield. This is particularly important when growing vegetables on large areas. In different countries vegetable crops are grown in different seasons. In Cameroun, for example, the rainy season falls between April and August; in the southeastern part of Nigeria the rainy season is between May and October. In Tanzania vegetables are grown during the cold season (May-August), as well as during the hot season (September-February) and rainy season (March-May). Vegetable growing during the hot season is possible only with irrigation. At heights exceeding 1500 m above

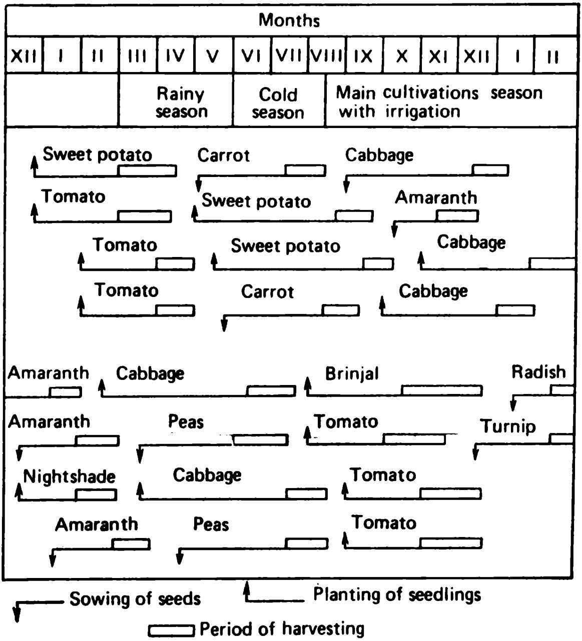

Figure 18
Alternation of vegetable crops during a year in Tanzania (from E.W.M. Verheij, 1982)

sea level cold-season vegetables are grown all year round, while in lower localities hot-season vegetables can be grown throughout the year. A scheme for growing 3-4 vegetable crops per year that is used in one of the farms in Tanzania is given in Fig. 18. Here, there are 15-20 days between crops cultivations during which the soil is prepared for the next crop.

Table 24

Sowing Times of Vegetable Crops During the Dry Season (Rabi) in Bangladesh
(from H. Brammer, 1977)

Dry season (Rabi)		
Early (September-October)	Average (November-December)	Late (January-February)
Cabbage Cauliflower Radish	Late cabbage Tomato Potato Sweet potato Onion Garlic Other vegetables of the celery family	Brinjal Eggplant Watermelons and other cucurbitaceae Pepper

In Bangladesh, for example, vegetables are cultivated mainly during the dry season. There are three times of sowing: early, average, and late (Table 24). In the rainy season the crops that require flooding are grown. In Thailand crops are also grown during the rainy season, i.e. rice is grown from July to October, and other kinds of vegetables are grown during the rest of the time (Fig. 19). In India all the vegetables are divided into winter crops (various kinds of cabbage, carrot, turnip, beet, small radish, onion, garlic, chicory, land cress, artichoke, anise, spinach, caraway, asparagus, bean, peas, tomato, etc.) and summer crops (watermelon, melon, pumpkin, bottle gourd, snake gourd, bittergourd, ridge gourd, cucumber, capsicum, brinjal,

<table>
<tr><th colspan="12">Months</th></tr>
<tr><th>VII</th><th>VIII</th><th>IX</th><th>X</th><th>XI</th><th>XII</th><th>I</th><th>II</th><th>III</th><th>IV</th><th>V</th><th>VI</th></tr>
<tr><td colspan="4">Rainy season</td><td colspan="4">Cold dry season</td><td colspan="4">Hot dry season</td></tr>
<tr><td colspan="4">Rice</td><td colspan="4">Potato</td><td colspan="2">Cabbage</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">Corn</td></tr>
<tr><td colspan="4">Rice</td><td colspan="4">Tomato</td><td colspan="4">Mung,bean</td></tr>
<tr><td colspan="4">Rice</td><td colspan="5">Garlic/anion</td><td colspan="3">Mung, bean</td></tr>
<tr><td></td><td></td><td colspan="3">Chinese cabbage</td><td colspan="2">Bean</td><td colspan="3">Corn</td><td colspan="2">Tomato</td></tr>
</table>

Figure 19
Alternation of crops depending on season in Thailand (from M. Seetisarn, 1977)

eggplant, portulaca, spinach, amaranth, husk tomato, yam, sweet potato, etc.) (D. V. Ter-Avanesyan, 1978). The crops of the winter season are sown on the plains between August and November, and the sowing of summer vegetables is done between February and March.

In Cuba the sowing, planting and growing of most vegetable crops are done in the autumn-winter (dry) period. The seedlings are sown and planted from September to Februa-

Table 25

Calendar Times of Sowing and Harvesting Vegetables in Two Climatic Zones

Crop	Southern India (tropics)*		Chile** (tropics – moderately warm zone)	
	Sowing period	Harvesting period	Sowing period	Harvesting period
Tomato	June-July Sept.-Oct.	Oct.-Dec. Dec.-Jan.	June-August	Dec.-Apr.
Pepper	March June-July	August Sept.-Dec.	Ditto	Ditto
Brinjal	Febr.-June	May-August	Nov.-Jan.	Ditto
Onion	Sept.-Oct.	February	Febr.-March June-Sept.	Aug.-Nov. Nov.-Febr.
Cabbage	Ditto	Dec.-Febr.	Nov.-March	March-Aug.
Carrot	Oct.-Nov.	January	All year round	All year round
Beet	Ditto	Ditto	Dec.-March	Apr.-June
Lettuce	Oct.-Dec.	Dec.-Febr.	All year round	All year round
Cauliflower	June-July	Oct.-Dec.	Dec.-Febr.	Apr.-June
Cucumber	Febr.-June	June-Dec.	Sept.-Nov.	Dec.-March
Melon	Ditto	May-July	Ditto	Jan.-Apr.
Watermelon	Ditto	Ditto	Ditto	Dec.-Apr.
Peas	Oct.-Nov.	Jan.-Febr.	Apr.-Oct.	June-Dec.
Bean	June-July	Oct.-Dec.	Oct.-Jan.	Dec.-May

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* From C. Bhujanga Rao, 1968.

** From D.D. Brezhnev and P.F. Kononkov, 1977.

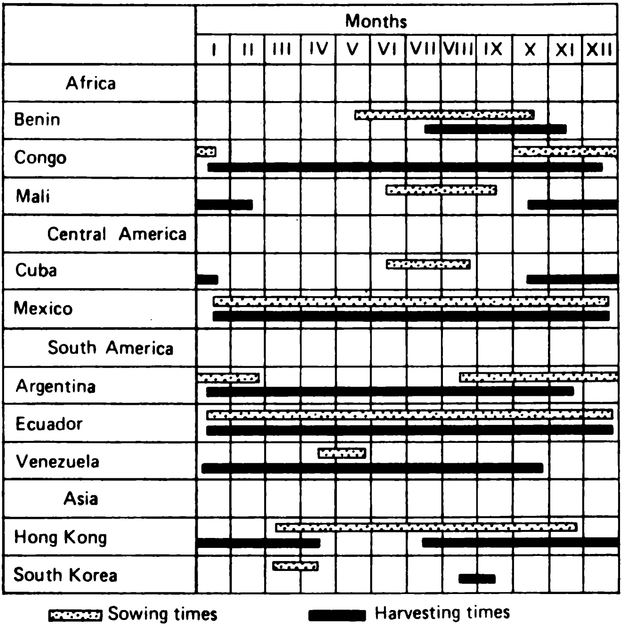

Figure 20
Terms of sowing and harvesting of sweet potato in various places of the world (FAO, 1978)

ry and the main harvest is from October to June. Some crops (e.g. leafy vegetables, eggplant, and pumpkin) are grown throughout the entire year.

In subtropical areas the vegetation period is limited and early (spring) and late (summer) vegetable sowings prevail. However, it is possible to obtain two or three harvests of different kinds of vegetables per year in home

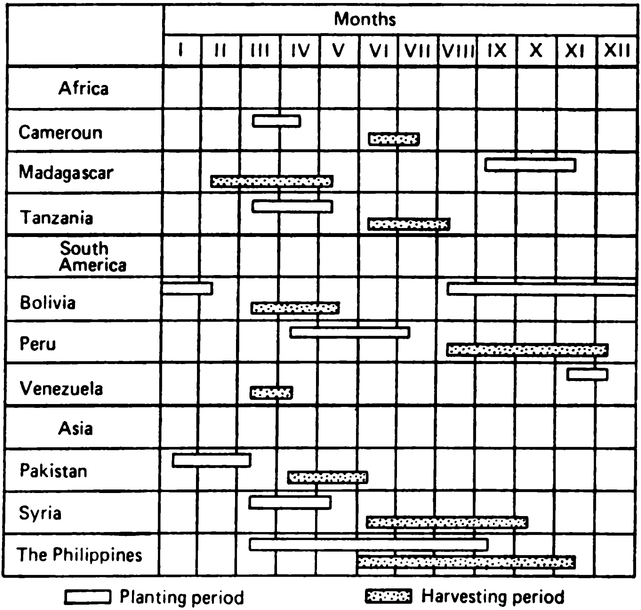

Figure 21
Terms of planting and harvesting of potato in various countries of the world (FAO, 1978)

gardens. In South America (Argentina and Chile), moving from north to south, the climatic conditions greatly vary. The northern part of this zone is in the tropics and subtropics, while the middle and southern parts are located in a zone of moderately warm and even frosty climate. Therefore, in these countries, some crops may be sown throughout the whole year while others are sown only in the autumn-winter period. The calendar times for sowing and harvesting of the main vegetable crops in the tropical areas of India and Chile are given in Table 25.

In home gardens, where vegetable crops occupy the most important place, they may be cultivated practically throughout the year. However, only when the growing season and sowing times are correctly chosen, can one obtain high yields. The optimum sowing and growing times depend on the country, province, and even region and may be established for each crop. The calendar times for sowing and harvesting sweet potato and potato in various countries of the world are given in Figs. 20, 21. It should be remembered that in every country, depending on the region, the times greatly vary. In the Hawaiian Islands practically all the types of vegetables are cultivated throughout the year.

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TROPICAL AND SUBTROPICAL SOIL SCIENCE

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It is a unique scientific guidebook on tropical soil science. The manual has received a warm welcome in many countries, particularly in Latin America, Africa, and Asia. It gives comprehensive information on various soils of the tropics and subtropics, thorough analyses of these soils, the results of their cultivation, and various means and ways for their more efficient use and conservation. A description of volcanic and alluvial soils is also included.

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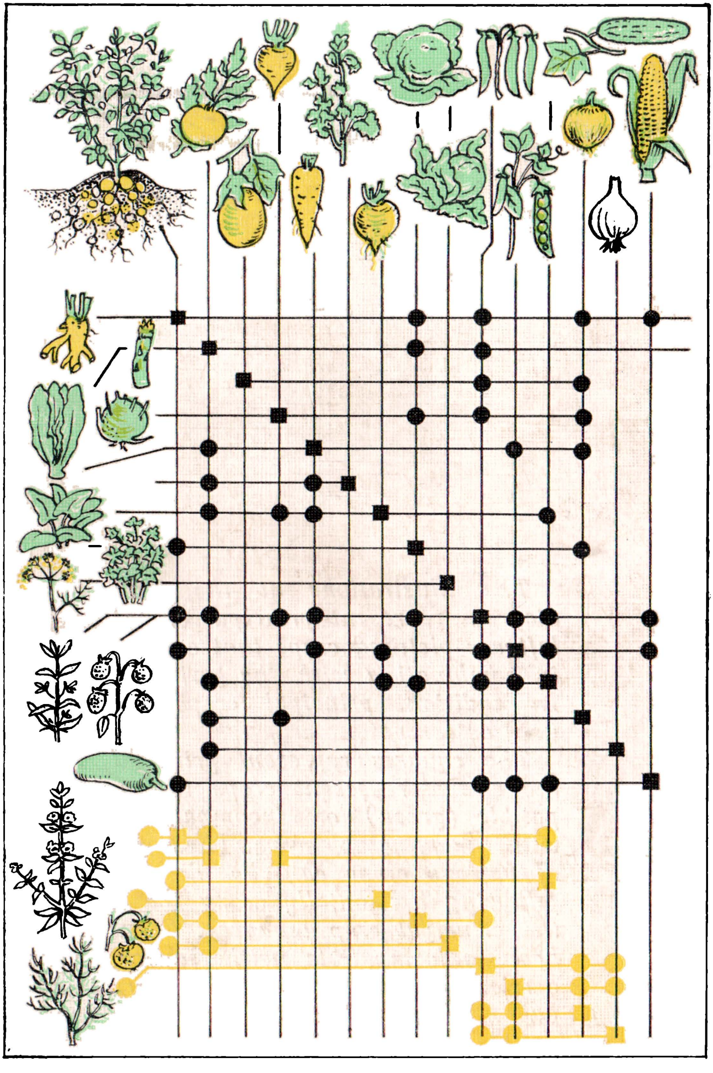
The illustrations at the top of the diagram represent principal crops. On the left are pictured crops that can be planted in combination with the principal crops. In addition, principal crops have been used as compatible crops.

The squares represent principal crops; the circles represent crops that are compatible (green) or incompatible (black) with the principal crops. The compatibility of various crops can be determined by following horizontally along the line with the principal crop (square). For example, bean is compatible with savory, strawberries, potato, tomato, beet, carrot, cabbage, peas, and corn. They are incompatible with fennel, onion, and garlic.



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